This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

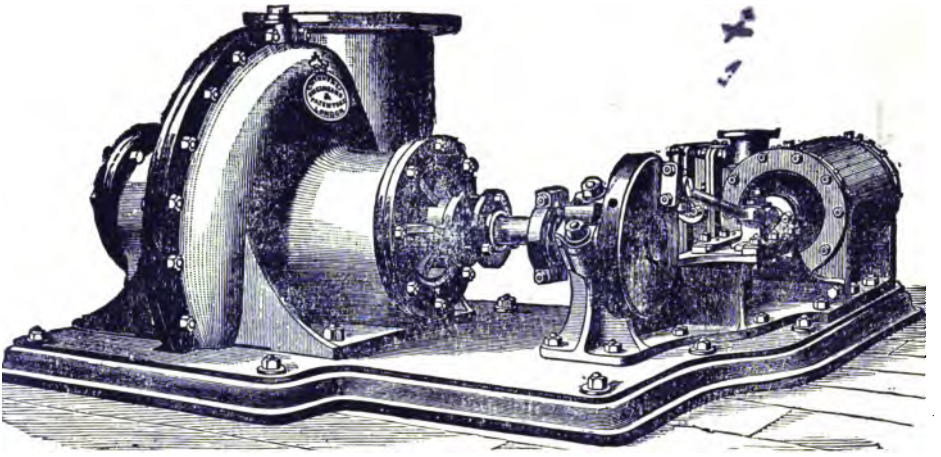
+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`



GWYNNE & CO.'S
PATENT CENTRIFUGAL PUMPING MACHINERY,

For Irrigation, Drainage, Manufacturing, and other Uses.

Constructed under the various patents of JAMES E. A. GWYNNE, C.E., who in 1852 founded this business, and has since conducted it.

GWYNNE & Co. have erected the Largest Pumping Machinery in the world; they have also erected more of all powers than any other Firm in existence, and are prepared to contract that their Machinery will do more work with less cost of coal than any other maker's.

THIS MACHINERY has received the HIGHEST Commendation; and Thousands of ENGINEERS, MANUFACTURERS, and others using it can be referred to in all parts of the world.

THE HIGHEST MEDAL AWARDED TO ANY COUNTRY, AT THE PARIS EXHIBITION, FOR THIS CLASS OF MACHINERY.

FOR MANUFACTURING PURPOSES,

They are largely in use; among others by Paper Makers, Brewers, Distillers, Dyers, Chemists, Tanners, Sugar Refiners, Bleachers, Calico Printers, Carpet Manufacturers, Engineers, and Iron Founders; Woollen Cloth and Blanket Manufacturers, Oil Refiners, Soap, Alkali, Salt, Starch, and Candle Works; Water Works, Lime and Cement Works, Quarries, Coal and Iron Mines, Sheep Washing, Public Baths. Cotton, Flax, Match, Felt, Oil, and other Mills, &c. &c. Numerous References to all the foregoing can be had on application.

FOR DRAINAGE WORKS,

G. & Co.'s Patent Centrifugal Pumps are in very extensive use, and some of the largest tracts of Land in this Country, and in Holland, Italy, Austria, France, Belgium, Denmark, Demerara, &c., are kept dry by their use,

FOR IRRIGATION WORKS,

They have been selected for very Extensive Works in Egypt, Turkey, Spain, France, Belgium, India, Ceylon, Java, China, Australia, Porto Rico, &c. &c.

FOR EMPTYING DRY OR GRAVING DOCKS,

They are quite unequalled, and will be found to excel all other arrangements, discharging a body of water in proportion to the lift, the speed of Engines and Power remaining the same; they will empty a dock in a shorter time and with much less power than is requisite with any other system; the first cost of machinery, the erection, and the foundations, and brickwork necessary are much less expensive than with any other arran[redacted] of keeping in thorough working order is merely nominal.

ESTIMATES FOR ANY SITUATIO[redacted]TION. LIST OF PRICES FREE on receipt of Stamped En[redacted]s engravings and much detailed information for Six Stamps.

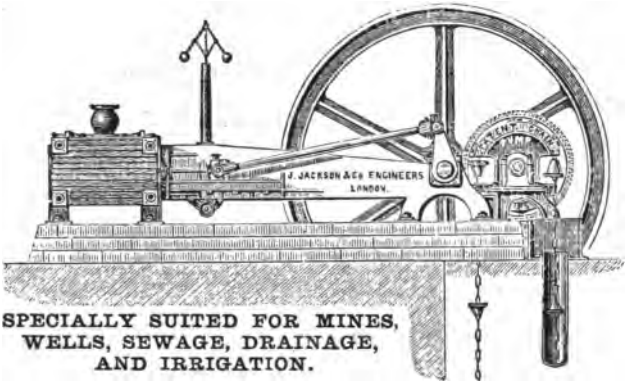
GWYNNE & CO., HYDRAU[redacted]NGINEERS,

ESSEX STREET WO[redacted]

J. JACKSON & CO., ENGINEERS,

LONDON, E.C.

BASTIER'S PATENT CHAIN PUMP.



SPECIALLY SUITED FOR MINES, WELLS, SEWAGE, DRAINAGE, AND IRRIGATION.

THIS is the most efficient PUMP ever introduced into public notice for *deep vertical* lifts. It is cheap in its first cost, requires no cleaning and little attention, and the cost of maintaining it with duplicate wearing parts is very small.

The water is lifted through the vertical tubes. At every interval of 50 yards a contracted part, or Working Barrel, is inserted, smaller in diameter than the main pipe, one of which is always placed at the lower end. An endless chain passes over the Driving Wheel at the top, going down free, and coming up through the tube, into which it enters by a bell-shaped mouth piece. On this chain are fixed India-rubber Discs, smaller in diameter than the main pipe, but fitting tight in the Working Barrels, so that all the water that enters is forced up and carried through the main pipe. The Discs being free all round from the pipe for nine-tenths of the whole distance, reduces the friction to a minimum.

Eighty-seven per cent. of the whole area of the tube is lifted in water. A 3½ inch Pump has lifted 120 gallons per minute, from a depth of 270 feet, with 10·75 indicated horse-power; other sizes in proportion.

These Pumps are now at work throughout England—sizes varying from 2½ to 15 inches diameter, and up to 300 feet deep.

Three were ordered by the India Office and forwarded with the Abyssinian Expedition, and since these were sent, various telegrams have been received from Sir Robert Napier ordering other lots to be sent immediately.

PUMPS WITH STEAM ENGINES, AND CATTLE, WIND, OR HAND-POWER GEAR,

Manufactured by the Proprietors of the Patent,

J. JACKSON AND CO.,

17, GRACECHURCH STREET, LONDON, E.C.

PRICE LISTS of the above and other Pumps and of improved Mining and Hydraulic Machinery generally, including Steam Engines, Tunnelling and Coal Cutting Machines. Also all other kinds of Boring Tools and Apparatus.

A Small Pump may be seen at Work on application to Messrs. J. H. GREENER & Co., *5, John St., Adelphi, W.C., who will also supply any information required.*

JOHN & HENRY GWYNNE,

ENGINEERS,

HAMMERSMITH IRON WORKS, LONDON, W.,

(City Offices: Cannon Chambers, 89, Cannon Street, London, E.C.),

MANUFACTURE

HIGH-PRESSURE AND CONDENSING STEAM ENGINES

To any required Power on the most Improved and Economical Principles.

PORTABLE AND TRACTION ENGINES.

Steam Boilers—Marine, Stationary, Portable and Vertical, in Iron or Steel.

PATENT DIRECT ACTING CENTRIFUGAL PUMPING ENGINES.

HYDRAULIC MACHINERY OF EVERY DESCRIPTION,

For Drainage, Irrigation, and Dock Work.

PATENT TEA-MAKING MACHINERY.

Water Wheels, Turbines, and Mill Work in General.

PAPER-MAKING MACHINERY

OF THE MOST IMPROVED CONSTRUCTION.

Hydraulic Presses—for Cotton, Seeds, Grapes, &c. Gunpowder Machinery.

COTTON GINS. HAND, STEAM, AND HYDRAULIC CRANES AND LIFTS.

EVERY DESCRIPTION OF CRABS, JACKS, &c.

SUGAR MILLS AND PANS.

Corn and Rice Mill Work. Sheep and Wool Washing Machines.

DOUBLE AND SINGLE-ACTION PUMPS AND AIR PUMPS.

WATER TANKS, IN CAST AND WROUGHT IRON.

BLOWING ENGINES AND PATENT FANS.

STEAM WINCHES & PUMPS FOR SHIPS' USE.

Fire Engines for Hand or Steam Power, and Floating Fire Engines.

HYDRAULIC RAMS, SINGLE AND DOUBLE-ACTING.

WIND MILLS, for Irrigating or Draining Land. DREDGING MACHINERY for Harbours and Docks.

GRINDING AND CRUSHING MILLS, for Mortar, Loam, Olives, &c.

EXCAVATING MACHINES FOR CONTRACTORS.

MACHINERY FOR GOLD AND SILVER MINES.

IRON HOUSES AND ROOFS FOR THE COLONIES. IRON CHIMNEYS.

Sluice Valves, Hydrants, and Water Pipes. Steam and Vacuum Gauges.
Shafting-Couplings, Riggers, and Toothed Wheels. Castings up to 40 Tons Weight.
Leather and India Rubber Belting, Patent Pipes, Joints, and Washers.

Illustrated Catalogues on application.

ESTIMATES GIVEN.

As there is another firm of a similar name, please address in full.

THE PRACTICE

OF

ENGINEERING FIELD-WORK.

WATERWORKS:

OR, THE

DISTRIBUTION OF WATER IN TOWNS UNDER THE CONSTANT AND INTERMITTENT SYSTEMS.

Gauging Streams,

SEWERS,

SEWAGE AND IRRIGATION.

BY

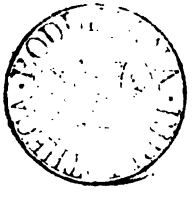
W. DAVIS HASKOLL,

CIVIL ENGINEER,

AUTHOR OF

"RAILWAY CONSTRUCTION," 4 Vols., £5 5s.; and "ENGINEERING FIELD WORK," First Volume, 20s.

VOL. II.



LONDON:

ATCHLEY AND CO.

ENGINEERING AND ARCHITECTURAL PUBLISHERS,

106, GREAT RUSSELL STREET, BEDFORD SQUARE.

1868.

183. e. 19.

LONDON :
SAVILL, EDWARDS AND CO., PRINTERS, CHANDOS STREET,
COVENT GARDEN.

PREFACE.

THE "Practice of Engineering Field-Work" was so kindly and favourably reviewed by the Press, and so well received by the Profession, that it is only with considerable hesitation we venture to add a second volume, now that a large first edition has been exhausted and a second one called for. More especially to the *Athenæum*, the *Builder*, and the *Architects' and Civil Engineers' Journal*, the author begs earnestly to offer his most grateful thanks.

Very great changes, however, have occurred in the practice of Civil Engineering since the work was first issued, and but few of us probably thought only a few years since that such very great alterations could take place in the calls on our time and labours; we had then almost more than enough, but there are now much too few for every grade in the profession. We are, nevertheless, very far from thinking that this in any way justifies the gloomy feelings which prevail with many, and which we must consider as unworthy of the Engineer; we are merely passing through an ordeal, similar to those we have witnessed before, though somewhat more severe than usual. Let us hope that we shall benefit by it; that it will chasten and purify.

A warning has long since been given, and for a long time it was loud enough to caution even the deaf; and yet none appear to have heard it in time. When the destroying storm came, it utterly swept away many of the innocent, but it has only just swamped for a moment the great guilty ones; they, *phœnix like*, will rise again; no sympathetic fears need to be entertained on their account. Upwards of twelve months since, as near as we can remember, a long and most able and truthful letter appeared in the valuable columns of "Engineering" on railway matters, and on the manner railway schemes were brought to bear, and in which they were carried on. Good, honest, and truthful advice was therein given, but like many such letters, it passed unheeded.

For a long time past it has been well known amongst working, or assistant, or resident engineers, or whatsoever name they may be called by, that on very many railway schemes, their position,

consistently with a sense of honour, was untenable, not to say detestable; very often indeed held at the pleasure merely of a company's *eminent contractor*, who either had everything his own way and to his own profit, whatever might be the result to the company, or who did not fail to put that pleasure in force; the advice given in the shape of a practical hint was simply, 'Look on calmly at all these transactions; take your salary and be silent; do not disturb the harmony between me and the Board; although you are considered a gentleman, a member of a profession of high standing, and in the opinion of shareholders the honest guardian of their interests.' This is said without affecting any special sympathy even for the unprecedented sufferings which shareholders have lately endured, for we all know but too well that it is quite sufficient at any time to raise a warning voice in protection of their interests to be then and there crushed without one of them stretching forth a finger to prevent it. This is almost proverbial amongst professional men with any long experience in the actual labour of constructing works; it is almost equally well known that if you will but swim silently in the dirty current you will be a successful winner. At home or abroad, it is the same thing in respect of a very great number of railway undertakings.

It was at the very time, even to a month, and for some time after, when the last great financial and railway storm broke out, that the following occurrence took place, not in a comparatively unknown part of the world, but on a railway constructing only a few miles from London: About 600 yards of footings in a tunnel were entirely left out of the work, although they were allowed for in the monthly certificates, and measures were taken to silence the inspector; the level of rails was raised about two feet to conceal the "job" from the inspecting officer when the time should come for opening the line. In many places, more particularly where the ground was soft, the embankments sunk very considerably below their proper level; to avoid the work of raising the rails and of ballasting according to contract, no sooner were the proper levels given by the engineer, and his back turned, than some one came after him, of course not the contractor, and had every one of the level pegs driven down to suit his own convenience. In consequence of boggy ground many of the embankments had settled down and slipped very considerably, and the proper centres for the rails were "nowhere;" when the engineer commenced setting out the centres for the curves of the permanent way, he was informed that it was quite unnecessary, that he was giving himself needless trouble, and that the platelayers were quite capable of setting out the curves, and accord-

ingly so the work was done; what those curves are like may be ascertained some of these days with unpleasant consequences. So utterly disgusted was the gentleman who had to do the work, that he threw up his engagement, *at a time* when the most able men were looking for employment in every direction and in vain. Had such things occurred in an out-of-the-way place, in Turkey for instance, we should have thought less of the circumstance; but this was in one of the home counties. We believe, however, that this is by no means uncommon in railway works; and the result of this, that, and the other cheating, deceit, and imposition is the present state of railway collapse, and of public confidence in engineering undertakings generally, but certainly more particularly railways.

We do not by any means write these words with feelings of vain regret; on the contrary, we say the sooner we pluck ourselves out of anything so useless as mourning and gloom, the better for ourselves and the many who are waiting for railway engineers to awaken to something beside railways, which for a time are doomed, at least until great changes take place. We believe that there are still many paying railway lines to be constructed at home, if the localities are sufficiently studied, and suitable curves and gradients adopted; but they must be cheap, and cheap lines do not suit contractors, and for some time it has been usual not to inquire "who is the engineer?" nor "who is the chairman?" but "who is your contractor?" For a long time past this has been the great puff to railway schemes in the opinion of the public; they forget that your *eminent contractor* requires his eminent prices, and conditions, sub rosâ, or otherwise.

These and many other similar conditions relating to the railway interests, have led us to submit with all humility to many of our professional brethren whether it is not possible to open up something like a new field on the subject of irrigation in connection with sewage; we use the expression 'humility' in all earnestness, because it may be considered, perhaps with justice, that we have no right to make suggestions to those who know at least as much as ourselves. But, in these strange times we venture to believe that it behoves all of us to speak plainly, so that we speak honestly.

If it were possible to imagine the existence and reality of the "Philosopher's Stone," we could almost think it must lay in some form of the practice of the engineer, when he is making roads and railways, docks and harbours, canals, irrigations, and waterworks, and reducing the pain of animal labour by the introduction of the power of machinery; it has been said that to some extent many of these works have been overdone, and railways are

in a special disfavour; we have, however, never yet passed through a district which had not been improved by railways, and the failure we believe lays in the fact that both at home and abroad we have omitted the construction of other works in connexion with them, which would have been beneficial in themselves, and would have greatly improved all railway property. We refer more particularly to what may be done in agriculture and in irrigation, more particularly still with the assistance of sewage, and on which to a certain extent waits the question of towns' water supply.

We hope we may venture respectfully to submit to the Profession that agricultural civil engineering, as distinguished from agricultural mechanical engineering, has been somewhat neglected, although it must be admitted that great obstructions have been cast in the way of the improvements that might be desired, which would so greatly benefit immense estates, and would cause so many millions of millions of blades of grass to grow, where now not one is to be seen.

We very readily admit that those obstructions are thrown in the way by men from whom a very different action might be expected, and it is not encouraging to find that such a thing as a rabbit warren may be made to stand in the way of a great local improvement, earnestly called for by some thousands of population. No doubt these obstructions are to be overruled, but this often requires the influence of a "King John," to borrow a most meaning and happy expression from the columns of "Engineering," who may often consider such small matters as beneath his notice.

This may not be the case as regards many younger engineers at the present time, and good may result out of misfortune. We believe that a great deal may be done in the way of agricultural improvement, and more particularly irrigation, and that all the railway interests would earnestly join in giving support to any projects of the kind within their several districts. It would be more profitable for them to run over fertile hills and plains than through a blank country, and at present we have plenty of such from one end of the land to the other. We can scarcely think they would fail to give support and facilities to any well considered project of the kind, because they themselves would be amongst the first to feel the commercial benefits. Abroad particularly, some railway companies have been made to feel, severely and ruinously, notwithstanding a guarantee, the results of constructing an expensive railway through a blank country, and neglecting all local and agricultural improvements, though a *naturally* most fertile country was confided to their *management* (!) for twenty or thirty miles on each side of them. We have

already called attention to this in our "Railways in the East," more particularly as regards the Smyrna and Aidin railway, which absorbs, we believe, almost all, if not quite the existing traffic, and yet barely pays expenses; but then everything in the shape of roads, irrigation, or culture has been ignored, and the company seems to have expected that the traffic would drop solidly and materially from the clouds; they did not see that it could only come indirectly from that source, and yet it is said, that highly eminent and scientific gentlemen of Indian reputation had the control of the undertaking. Mr. J. P. Roberts, in his very able and valuable paper on "Irrigation in Spain," observes that it is almost useless to irrigate a valley, if it be not opened up by good roads and railways; and our experience goes to prove that it is equally abortive to make expensive railways through countries deficient of culture and roads, and in all warm climates, where there is no irrigation, there is but very little profitable agriculture. Under such circumstances where can railway traffic come from? It is certainly somewhat strange that a poor Turkish peasant should have perceived that which escaped the observation of railway engineers, directors, and managers; and yet such is the fact. We have seen him leading and twisting a little stream over his ground, and producing a bountiful crop, where all around him was barren and desolate, simply for want of a little water, for the vegetable soil was everywhere five and six feet deep. We cannot but think that under such circumstances, those having charge of a great railway undertaking, should have seen the advantages to be derived from having a contractor's plant already on the spot and at their command, and should have perceived the necessity of making use of it, in order to produce general improvement over some three or four thousand square miles of country where the government was prepared to afford every possible assistance and facility. More or less, this has been the case with many of our Indian railways. When those works were constructed, had the subject of irrigation been considered, we venture to think that more satisfactory results would have been obtained. We all know what a large proportion of the expenditure on works has to be borne by the carriage and transport of plant, particularly to inland regions abroad.

To a certain extent, and in some cases, perhaps, considerably so, we venture to submit that many of the above observations bear upon the districts traversed by railways at home. We have yet many an extensive area varying from ten to a hundred square miles, where from want of drainage and irrigation the cultivation is all but *nil;* many a noxious marsh and morass for want of a little drainage, and many a barren hill side where

streams now running to waste, might be led to produce yearly improving pastures.

With all due deference to our great hydraulic engineers, we cannot help thinking that many of the noble schemes lately projected for the water supply of towns, might be improved by having irrigation combined with them; we think they might be made to produce more beneficial and profitable results.

Every engineer who has had much to do with surveying, trial levelling, and examining hills and valleys, must have observed the number of streams we have running to waste, so far, at least, as all agricultural benefits are concerned, and yet there can be no doubt that every such stream carries wealth with it, and that in an immense number of cases they might be led to produce pastures and meadows.

It is in regard to these views, and to what we consider engineers may yet do in respect to improved agriculture, that we have ventured to trouble the profession with an additional volume to our "Practice of Engineering Field-Work;" and in doing this we have endeavoured to embody all the opinions we could gather of the most eminent men on the subjects of the distribution of water for town supplies, of sewage, and of sewage and irrigation. The discrepancies that have to be reconciled are very numerous: this we may partly attribute to the fact that we have yet much to learn on all these subjects, and partly to the maintenance of party views, which will always obtain more or less, and keep us in a state of healthy competition and emulation. There are many of the opinions which we could have wished to give more in abstract, but we found it difficult, if not impossible, to do this with justice to those from whom they emanate; in abstracts of opinions so diversified, a few words left out here and there may totally alter their meaning, and to have translated them in language of our own would have been merely to make our appearance in borrowed features, a practice we have always avoided. By giving a variety of complete independent opinions, we believe we have adopted the best course to enable the student to judge for himself under a different combination of circumstances, and to avoid the necessity of adopting a 'nostrum' or formula applicable to all cases, however dissimilar.

The subject of sewage and irrigation is now becoming an important one all over the civilized world. In Bombay, we believe, they are considering the propriety of throwing the whole sewage into the sea, although we think they might adopt a more natural and more profitable course; at present, as we understand, the whole of the ordure of this immense population is carried out of the town by hand every morning; we cannot but consider that

this is one instance where they might profitably adopt the patent of Dr. Angus Smith and Mr. Macdougal, or at least the application of the principle, and we think also with more benefit to public health ultimately. We are of opinion that, at least, it should be tried before going to the expense of constructing an enormous sewer, with an outfall such as we have at Barking, and with probably similar consequences.

From an able article in the last number of the "Bombay Builder," 5th December, 1867, we learn that the proposed drainage scheme has been abandoned. As a remedy, some of the medical authorities appear to suggest a delay of two or three years, which, of course, may mean half a dozen years; in the meantime cholera or the plague may suggest that delays are dangerous in sanitary matters; and from all we have been able to learn we cannot help thinking that the sanitary conditions of Bombay are not to be trifled with. We are disposed to think that it is one of those places where circumstances are such that many valuable experiments may be made, and which might enable Bombay to set an example to some cities in Europe, at the same time that they established a system of disposing of the sewage which would pay.

There is no doubt that in regard both to sewage and sewerage matters, opinions are changing very rapidly; the separation system, as regards rainfall and sewage, not long since so utterly condemned, has come into favour for important towns and under powerful auspices; we are disposed to believe that before long, in a similar way, the use of sewers for carrying away closet sewage will become obsolete under some conditions; that which has been effected on a small scale may be carried out on a much larger one, if a few clever chemists and engineers will only set their heads together free of all prejudice, and all past antipathies. We certainly think highly, and indeed who could do otherwise, of what has been accomplished with so much talent and perseverance at Croydon, by Mr. Baldwin Latham. But we venture to question whether such a system of irrigation would be acceptable throughout the length and breadth of the country, and for inland towns of so much more importance than Croydon.

The results obtained for years past at Edinburgh, and more lately at Croydon, are too important to be practically neglected any longer in all similar cases, and the deductions obtained by the sewage commissioners at Rugby, after eight years of experiments, should no longer be ignored; it is time, in these matters as in others, for the engineer to be up and doing, without, however, considering himself bound to adopt exactly, and always, one system or principle of sewage.

The fitness of Sewage, under all conditions, for cereal and root crops, has been under discussion for some years, and most of the more prominent advocates of Sewage manure have been in favour of its application, principally for the culture of rye grass. This, of course, has very much restricted the nature of projects for the disposition of town Sewage. Much of this restriction is now removed, by the great successes obtained by the Essex Reclamation Company in the application of Sewage, in competition with common manure, for corn and mangold. In every respect the results in favour of the Sewage have been most satisfactory: as regards the quantity of produce, both corn and root, as well as the economy of the manure, the most decided advantages were obtained from Sewage, and in the matter of the mangold particularly these advantages were very great indeed.

Well-considered schemes of irrigation have never yet failed to produce happy results; town manure may now be easily obtained. Many streams and springs lay high enough to be conducted along the sides of hills and even mountains, and then used for irrigation. Small reservoirs may be constructed in high-level gorges, and many boggy summits may be tapped and their waters drawn off from where they are only mischievous, to there where they may produce the happiest results. It is not unworthy of the engineer to cover some thousands of square miles, now barren or but unprofitably cultivated, with pastures and fattening flocks. Even at home very great results are to be attained, but abroad they are incalculable; in the countries we have visited in the East large herds of cattle in excellent condition are to be seen in the spring-time of the year, but in summer they are starved, because the country is made barren for want of irrigation; it is unfortunate for railway shareholders in such countries, when they have made large ventures in such undertakings, to find them so managed that petty personal intrigues completely obscure the broad path of duty. Great results are yet to be obtained in the rich empire of Turkey, as well as in India, but it must be under a very different rule, generally, to that which has obtained hitherto.

CONTENTS.

CHAPTER I.

WATERWORKS.

THE DISTRIBUTION OF WATER FOR TOWN SUPPLIES.

Catchment Basins, 1.—Variations in Rainfall, 2.—Peculiarities of Catchment Basins, 4–8.—Description of the Features of Catchment Basins, 9–12.—Chalk District and Borings in Chalk, 13–16.—Wells and Springs, 17.—Hardness of Water, Tests, 18–20. Peaty Waters, 21.—Impurities of Rivers, 21.—Presence of Sewage; Tests, 23–29.—Paris Water Supply, 30.—Vienna Supply, 31.—Advantages of Hard Waters, 32.—Experiments on the Action of Filters, 33.—Supplies from Deep Wells: the Kent Waterworks, 34–37.—Double System of Pipes for London, 38–41.

CHAPTER II.

THE DISTRIBUTION OF WATER FOR TOWN SUPPLIES.—*continued.*

NOTES ON THE CONSTANT AND THE INTERMITTENT SUPPLIES.

Specification of Brighton Water Supply, 42.—Manchester Supply, 46.—Newcastle-on-Tyne Supply, 48.—Edinburgh Supply, 49.—Cambridge Supply, 54.—Bristol Supply, 57.—Carlisle Supply, 58.—Croydon Supply, 59.—Opinions of the London Waterworks Engineers on the Intermittent and Constant Supplies, 60–66.—Mr. Bateman's and Mr. Easton's Opinions on the Constant Supply System, 67–69.

CHAPTER III.

GAUGING STREAMS.

The Discharge of Water in Overfalls, 70.—Form of Notches, 71–73.—Pipe Formulas, 74.

CHAPTER IV.

SEWERS.

Considerations respecting the Design of a System of Sewers, 75–80.—Brick Sewers and Earthenware Pipes, 81–91. — Tables and Memoranda for Estimates and Specifications, 92–102.

CHAPTER V.

SEWAGE AND IRRIGATION.

State of the Sewage Questions relating to Large Towns, 103.—Deodorisers, 107–110.—Dr. Frankland on Sewage, 110.—Dr. Angus Smith, 112–141.—Dr. Letheby, 129.—Professor Way, 119–121.—Drs. Hoffman and Witt, 115.—Mr. Mechi, 124.—Mr. Lawes, 125.—Mr. M'Clean, Past P., Inst. C.E., 126.—Value of Sewage, 115, 118, 132.—Edinburgh Meadows, 118–146.—Craigentinny, 119–147. — State of the Thames at Barking Creek, 128.—Dr. Marsden on the State of the Atmosphere in the Neighbourhood of Sewers, 133–141.—On the Gases Evolved from Sedimentary Matters, 135.—Method of Making Experiments, 136.—Vegetable and Animal Life, 144.—Effect of Sewage on the Teredo, 145.—Sewage and Irrigation at Croydon, 151.—Third Report of the Sewage Commissioners, 154.—Sewage Application and Results, 155.—Works of Irrigation, 172.

CHAPTER VI.

TRAVERSE SURVEYING.

Practical application of Traverse Surveying, 177.—To reduce Horizontal Angles to Plotting Angles, 181.—To Construct the Plan, 182.

WATERWORKS.

CHAPTER I.

WATERWORKS.

Catchment Basins — Variations in Rainfall — Peculiarities of Catchment Basins — Wells — Springs — Chalk Borings — Hardness of Water — Tests — River Impurities — Existing instances of masses of Sewage in River Waters — Tracing the Improvement down the Current of Streams — Supplies to Paris and Vienna — Hard Waters — Experiments on Filters.

A CATCHMENT Basin is an area of land which receives and intercepts a certain amount of rain falling on it; it may consist of a few acres or many square miles. To those who are studying the subject of waterworks, the particular features of various catchment basins are of great importance.

Catchment basins are generally drained by rivers or their tributaries, and usually also they are surrounded by high grounds, and sometimes lofty mountains. It is more particularly in the latter case that catchment basins are valuable on the subject of waterworks, on account of the large amount of rain which is usually collected by mountain ridges.

The upper basins of the main tributaries of the river Severn consist of about 130,000 acres, and the summits of the catchment basins are about 3000 and 2500 feet in altitude, and the average annual rainfall is probably not much less than 150 inches. In some parts of Essex the annual rainfall has been said to be less than 20 inches. The variation that may occur in the annual depth of rainfall is well shown in the following returns from various parts of Great Britain; they explain how much the rainfall may differ in one year from that of another; and at different places, altitudes, &c.

LONGDENDALE VALLEY.

Years.	Rhodes Wood Reservoir. 520 feet above sea level. Inches.	Woodhead Reservoir. 680 feet above sea level. Inches.
1855	34·49	40·33
1856	49·16	50·89
1857	40·04	46·08

LONGDENDALE VALLEY—(*continued.*)

Years.	Rhodes Wood Reservoir. 520 feet above sea level. Inches.	Woodhead Reservoir. 680 feet above sea level. Inches.
1858	42·77	45·54
1859	46·34	53·35
1860	47·85	53·69
1861	40·22	44·24
1862	47·28	49·63
1863	48·04	53·77
1864	38·50	43·52

CUMBERLAND AND WESTMORELAND LAKE DISTRICT.

Place of Observation.	Height above sea level. Feet.	Number of years.	Mean Rainfall. Inches.
Keswick	258	10	59·6
Loweswater	336	10	67·29
Crummock Lake	260	10	84·1
Gatesgarth	290	9	114·7
Eskdade Head	—	7	77·9
Wastdale Head	247	10	101·4
Selside	736	5	73·5
The Hough, Troutbeck . .	503	10	79·3
Ambleside	190	6	79·6
Seathwaite	—	9	140·5
Stonethwaite	340	7	111·4

VARIOUS PARTS OF ENGLAND.

Years.	Greenwich Observatory. Inches.	Hastings, Kent. Inches.	Dickleborough, Norfolk, about 120 feet above sea level. Inches.	Chesham, Bucks. Inches.	Aylesbury, Bucks. Inches.
1838	21·64	26·64	—	—	—
1839	26·99	34·67	—	—	—
1840	16·43	25·62	18·86	—	—
1841	33·26	42·15	30·65	—	—
1842	22·57	26·68	24·96	—	—
1843	24·47	30·43	28·37	—	—
1844	24·96	32·40	24·15	—	—
1845	22·34	31·25	26·52	—	—
1846	25·29	35·50	22·33	—	—
1847	17·61	22·36	18·40	—	22·5
1848	27·94	43·53	32·42	38·41	34·7
1849	23·69	32·54	23·88	29·05	28·2
Mean	23·93	31·98	25·05	33·73	28·4
Lowest	16·43	22·36	18·40	29·05	22·5

LOCH KATRINE DISTRICT (GLASGOW WATERWORKS).

Situation of Gauge.	High above sea level. Feet.	Annual Rainfall. 1855. Inches.	1856. Inches.	1857. Inches.
Bridge of Turk	270	39·0	48·3	54·8
Between Glen Finlas and Glen Ledi	1800	56·1	—	48·3
Glengyle	380	65·5	79·3	91·6
Between Loch Ard and Loch Katrine . . .	1500	74·1	74·2	—
On the Slope of Ben Lomond	1800	69·9	81·0	85·5

AVERAGE RAINFALL OF A NUMBER OF YEARS IN THE SAME DISTRICT.

Valley Gauges.	Height above sea level. Feet.	Number of years.	Mean Rainfall. Inches.
Loch Venekar	275	4	64·7
Bridge of Turk	270	11	60·2
Glengyle	380	11	92·4
Loch Dhu	325	4	91·7
Mountain Gauges, Loch Drunker	420	4	71·3
Between Glen Finlas and Glen Ledi	1800	10	59·9
	830	4	86·2
Between Loch Chou and Loch Katrine	1500	10	84·8
On Slope of Ben Lomond .	1800	11	91·9

When the gathering ground is extensive; when the levels vary greatly, at some hundreds of feet; where there are numerous streams and tributaries, the accurate gauging of streams and rainfall is often an intricate question, and it is frequently difficult to reconcile discrepancies.

Almost always there will be a much heavier rainfall on one side of a chain of hills than on the other. The number of troughs or valleys towards the summit of hills will form catchment basins for clouds; where these do not occur, the clouds will often pass on without depositing so much rain.

The amount of rainfall increases generally with the rise of levels, but more rain falls on the flanks of mountains than at their summits, more particularly under the conditions above referred to.

In the West of England, it is generally found that after the clouds have come over the westerly summits, a large amount of

water is caught in the first troughs of a valley; so that, at a much lower point on one side of a ridge, there may be a heavier rainfall than at a higher level on the other side of the ridge.

Where the sides of the hills surrounding a gathering ground are steep, the rainfall will flow off rapidly into the streams, and more particularly where a rocky stratification shows itself on the surface, and there is not much room for absorption and percolation.

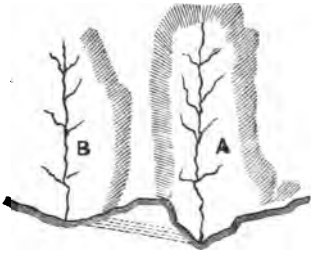
On flat table-lands, such as moorlands, with a great depth of absorbing and undrained material, there may often be heavy rainfalls which will be detained and evaporated, but from which, being drained, a large amount of water would flow off at a lower level. After a long wet season, however, the absorbing material becomes saturated, and much of the rain will flow off the surface at once, and probably a much larger quantity will percolate down to an impermeable stratum, from whence it will flow off in springs; the proportionate quantities given off by these may greatly depend on the rate of inclination of the substratum over which the water has flowed.

The same observations will bear upon the sands and light gravels overlying such formations, as the Lias; areas of many miles under the lower greensand overlying this formation are often, even after very heavy rains, perfectly dry, because the water has been absorbed and discharged at a lower level; frequently some hundreds of feet lower. The inclination of the lower beds will determine on which side of a hill the water will flow out, except such portion as may meet with a large rent or fault, and which may be carried off in another direction.

The aspect or bearing of mountains and hills, and of the troughs and subsidiary valleys with which they are furrowed; their proximity to the sea, and their altitudes; their geological construction; the inclination of the sides; the overlying materials; the dip and formation of the substrata: all being important elements as to the amount of rain fallen, the evaporation, and the discharge of water, it will be readily seen that great discrepancies frequently arise between the amount of rainfall and the discharge, until by proper observations these are more or less reconciled. To accomplish this thoroughly often, however, consumes a great amount of time.

It will also be seen that, over an extensive gathering ground of such a character as we have above referred to, numerous rain gauges to measure the rainfall, and numerous overfalls to gauge the quantities discharged by streams, are frequently necessary where we look for anything like close approximations.

In the accompanying sketch let A and B, be two arterial



streams, with their tributaries, passing through two parallel valleys. They may each discharge exactly the quantity of water due to the respective rainfalls and areas of the gathering grounds. It may, however, happen that the geological formation of the ridge between the two valleys is such as to divert a large quantity of water from B to A, as shown in section. If rain gauges were kept in each of these valleys, there might be but little difference in the rainfall recorded for each; the overfalls on the streams might, however, give a very different account, for a large portion of the rainfall falling on one half of the valley B, might percolate into A. In some cases, water is thus fetched from distances far beyond the apparently legitimate range of the gathering ground.

This will be sufficient to explain the importance of a system of stream gauging in combination with rain gauges, the latter being so disposed as to obtain as nearly as may be an account of the differences of rainfall in different situations, the object of the two being to ascertain the rainfall, the discharge, and, *cæteris paribus*, the evaporation and absorption.

Local causes may produce great differences in the quality of water flowing off gathering grounds.

The Silurian formations, the granites, the older rocks generally, as well as volcanic districts, throw off water very rapidly; these and the millstone grit formation, are all very favourable for giving fine soft water.

Sandstones and shales form excellent filters, and the water that flows from them is always very pure, and generally of only one or two degrees of hardness, and often less.

The old and new Red Sandstone formations have great powers of storing water, as exhibited by the numerous wells formed in these formations.

In the Chalk, unless where the sides of the hills are steep, a large proportion of the rainfall is absorbed, and carried down to the flint beds, where it is stored in large sheets of water; in this formation also water is often fetched from great distances by a flat underlie. There, however, the water is very hard, though it forms one of our most agreeable drinking waters.

It often occurs that in gathering grounds, otherwise unexceptionable, there may be here and there certain portions yielding water of an inferior character, such, for instance, as that flowing

from decomposing peat, or from a tract of land highly manured; the quantities of water discharged by such areas have often to be ascertained; in a like manner and for like reasons it may be necessary to gauge the water discharged from metalliferous districts.

It may also be necessary to gauge separately the quantities of hard and soft waters, and of the purest, such as may be required for dye works, or for chemical or print works; or to ascertain the discharge from streams appropriated by existing mills or other interests, as also of such waters which it may be intended to substitute for them.

The object of a town's water supply is often combined with the regulation of the working volume of water in a river; this frequently occurs when the supply is to be collected from any extensive gathering ground. The surplus and flood waters of the wet seasons are impounded in reservoirs, where large quantities are stored and provision is thus made for an equable and regular distribution during the dry times of the year. Even during the dry seasons, in mill and factory districts, the water running at night may be impounded, and afterwards discharged during the working hours of mills and manufactories. It is also often necessary to see whether the small reservoirs, or "lodges," attached to mills, intercept sufficient water during the night to satisfy the requirements of the following day, until the water comes down from the next neighbour above stream.

We trust that enough has been said on most of the above subjects, to explain to the student the high importance of a close study of gathering grounds, in reference to the great amount of information that may be expected in reference to rain and stream gauges, and how numerous sometimes these will have to be. He will not fail to observe that under such circumstances, not only great care, but also the most perfect regularity and system are required in keeping the various records, to prevent even a semblance of confusion. It is very different to all ordinary railway surveys, and requires much more thought and attention, but it is infinitely more interesting generally.

The depth of annual rainfall varies very much in the British Isles, and great differences are frequently obtained at only a few miles apart. In the South it may not be much more than twenty inches in the low open country, whilst in the North it may amount nearly to two hundred, at high levels and in exposed situations. A few hundred feet difference of level, or a different aspect, may occasion a difference of ten to fifteen inches in the course of a year, and at one particular season, in gauges only three or four miles apart; as in Cheshire, at Todd's Brook Brinks, 29·5 inches, at

1500 feet above the level of the sea; and at Todd's Brook Reservoir, 38·39 inches, at 620 feet above the level of the sea; at Coomb's Ridge, only a few miles from the above, 35·85 inches at 1670 feet above the level of the sea; and at Coomb's Reservoir, about a mile and a half from the last gauge, the rainfall was 51·30 inches, at 720 feet above the level of the sea. All the above were measured in the year 1847, and although the staff gauge, which is defective, was used, its defects would not cause such differences. South-west of Rochdale, the rainfall in 1844 was gauged at 34·41, and in 1846 it was gauged at 61·11. Near Bolton, in 1843, it was gauged at 63·4, and in 1846, at 49·8.

In the Cumberland Lake district the average annual rainfall is estimated at 150 inches, and Mr. Bateman considers that it is much about the same in North Wales. On the west coast of the Highlands, in Scotland, there is no reason to believe the amount to be less. At Loch Katrine the average is 78 inches, and "the minimum fall of three successive dry years is 66 inches per annum."

The average annual rainfall on the Penine chain of hills which forms the backbone of England, separating Lancashire and Cheshire from Yorkshire and Derbyshire and the east and west watersheds of the country, is about 50 inches. The amount flowing off in dry years at the Manchester Waterworks, which lie in the heart of the district, is 33 inches per annum.

The depth of rainfall in inches multiplied by the constant 2,323,200 will give cubic feet of water on a square mile; and if multiplied by 3630, the product will be cubic feet per square acre.

Hence the following table:

CUBIC FEET PER SQUARE MILE FOR A GIVEN DEPTH OF RAINFALL.

Depth of Rainfall in inches.	Cubic feet per square mile.	Depth of Rainfall in inches.	Cubic feet per square mile.
0·100	232,320	0·525	1,219,680
0·125	290,400	0·550	1,277,760
0·150	348,480	0·575	1,335,840
0·175	406,560		
0·200	464,640	0·600	1,393,920
0·225	522,720	0·625	1,452,000
0·250	580,800	0·650	1,510,080
0·275	638,880	0·675	1,568,160
0·300	696,960	0·700	1,626,240
0·325	755,040	0·725	1,684,320
0·350	813,120	0·750	1,742,400

CUBIC FEET PER SQUARE MILE FOR A GIVEN DEPTH OF RAINFALL—(*continued.*)

Depth of Rainfall in inches.	Cubic feet per square mile.	Depth of Rainfall in inches.	Cubic feet per square mile.
0·375	871,200	0·775	1,800,480
0·400	929,280	0·800	1,858,560
0·425	987,360	0·825	1,916,640
0·450	1,045,440	0·850	1,974,720
0·475	1,103,520	0·875	2,032,800
0·500	1,161,600	0·900	2,090,880
		0·925	2,148,960
		0·950	2,207,040
		0·975	2,265,120
		1·000	2,323,200

A description of the Lyme Park gathering ground will assist in calling the student's attention to the various practical considerations that have to be borne in mind in relation to Catchment Basins.

The principal supplies of water will be derived from the upper sources of the Lyme and Poynton Brooks, and their tributaries, which it is intended to collect in reservoirs, and convey to the town, as occasion may require.

The catchment basin from which the water will be collected comprises an area of 3618 acres, the greater part of which is from 500 to 1300 feet above the level of the sea; it is principally hilly pasture land, on a substratum of millstone grit in the higher parts and sandstone in the lower, from which numerous springs issue.

The land in a large proportion of the area has steep inclinations towards the watercourses and brooks, which almost entirely run through and over sandstone, nearly in the direction of the dip of the strata, and with the rapid falls of the streams, tend to accelerate the collection and conveyance of the water, whilst very favourable localities for the construction of reservoirs present themselves in various situations.

According to the register of a rain gauge kept at Lyme Park, it is estimated that the fall of rain will never be less than 38½ inches per annum.

From gauges of the flow of water in Lyme Brook, it is calculated the collective quantities of water which will pass into the reservoirs will average more than 6,400,000 imperial gallons per diem.

The available fall of rain is estimated at 30 inches per annum.

As might have been anticipated, from the character of the district, and the comparative absence of peat mosses, none but

the most extraordinary floods affect the purity of the streams. A large proportion of the water proposed to be applied to the intended works will be surface water, so free from impurities and stains, that even after very heavy rains it speedily becomes clear and colourless when allowed to settle in a reservoir.

It is also particularly worthy of remark, that frequent showers often fall on this part of the range of hills, and that they often occur when there is no rainfall in the valleys. Considerable quantities of water continue to run in the streams during the driest seasons; and from the experience of the last two summers, there is every reason to believe that the flow of spring water in the brooks will never be less than 1,000,000 imperial gallons per diem; consequently there will always be a sufficient quantity of cool, pure, and sparkling water running into the reservoirs to refresh them, and to keep the entire mass of water in constant motion.

It is intended to carry the water in cast-iron mains of 24 inches in diameter, to be laid about three-fourths of a mile through the lands of the owner of Lyme Hall, who is an assenting party to the project, and for the remaining nine miles along the turnpike road, a very wide and direct thoroughfare, fully capable of affording every facility for the construction of all the necessary works.

The waters of the Lyme and Poynton Brooks unite at Barlow Fold, between Norbury and Poynton, about three miles and a half below Lyme Park; and the stream then proceeds for about five miles and a half in a circuitous course, until it enters the river near Cheadle. The springs and drainage below the proposed works, extending over about 4500 acres, add considerably to the volume of water in the brooks. It is proposed to secure water for the collieries and ornamental property, agricultural and other purposes required by the owners and occupiers of land on and contiguous to the streams, by clauses in the Act rendering compulsory and imperative on the Waterworks Company to maintain constant flows in the streams, after the reservoirs are constructed.

There are six mills on the brooks; viz., one on the higher part, near Norbury, and five on the lower part, near Cheadle. Small water-wheels are worked at all these mills, and it is proposed to compensate the parties in money for the abstraction of their water power. The Canal Company has also an interest in the surplus water of one of the brooks, and this interest it is also proposed to purchase.

In respect of property it is confidently believed that the Lyme Park Waterworks project will do less injury than any other project for supplying any considerable quantity of water to the town. The most important owners of the lands on the sites of the reservoirs and along the line of mains, are not opponents of the

measure; the remaining portion of the line of aqueduct is to be laid along the turnpike road leading directly to the streets of the town, where junctions with the existing mains and pipes of the Company can be effected with the greatest facility.

The strata, under what is called the lower part of the coal measure, form that portion of it in which the millstone grit rocks rise, which lie below the coal; the water therefore is not liable to be impregnated with impurities from the mineral character of a coal district. It consists principally of the millstone grit rock and of shale.

As regards culture, there is very little of the land under the spade or the plough; there is a large area of bare steep declivities, where mostly the rock breaks out on the surface, and much of it consists of precipitous precipices. There is some peat, the greater portion of which is in a state entirely dead. It is no longer vegetating, and nothing grows upon it. It is dead peat; very heavy showers carry away portions of it in its decomposed state, and to a great extent the water is turbid, but it is not permanently discoloured.

Mr. Bateman has given the following description of the catchment basin from which he proposes to supply the Metropolis.

The district "lying on the flanks of the mountain ranges of Cader Idris and Plynlimmon, North Wales, forms the upper basin of the main tributaries of the river Severn. Here the direction of the mountain chains, the heights of their summits, their proximity to the sea, their geographical position, and physical peculiarities, entitle us to expect a very large fall of rain. They are so similar in their general characteristics to the Cumberland and Westmoreland mountains that we should be justified in assuming (in the absence of more precise data), the recorded fall of rain in that part of the country, for that which might be expected on the upper drainage of the Severn."

A summit ridge or line of watershed, of irregular height and direction, extending from north to south, is crossed and broken by several parallel ranges of mountains extending from south-west to north-east, the intervening valleys on the west side of this irregular summit being *quite open to* westerly winds.

The valleys on this side, walled in as they are by mountains rising at their peaks to 2500 and 2900 feet in height, and so raising their heads above the general level of the rain clouds, form as it were so many funnels, up which the clouds are driven over the low passes at the summit line of watershed into the valleys on the east, where, sheltered from the wind, they discharge the bulk of their watery contents.

Under similar circumstances, in the Cumberland Lake district

the heads of the valleys and the easterly side of the mountain passes receive an extraordinary amount of rain, amounting in some cases to 150 inches as the average annual depth of rainfall.

The observations of the late Dr. Miller, in this particular district, show the gradual increase in the amount as you ascend the mountains up to considerable heights, and his observations have been corroborated by others.

As far as the rain gauge observations have been made on the Welsh district, there is reason to believe the rainfall will be as great as in Cumberland.

"From these observations we should be justified in assuming the fall of rain upon the valleys and on the hills, from which the Severn derives its supplies, at not less than 70 or 80 inches per annum, on an average of say three successive years of minimum rainfall.

"In these mountain districts, where it seldom ceases raining for many days together, storage for 120 days' supply would be ample provision, but I have endeavoured to obtain reservoirs of capacity sufficient to last out 140 or 150 days, without taking into account the produce of the springs and streams during that period, but which would, nevertheless, amount to a considerable quantity.

"Among the many districts which present themselves for consideration, two admirable ones have been selected, each capable of supplying, in addition to the natural volume of the streams in dry weather, something more than 100 million gallons of water per day to London, after giving compensation in water to the streams on which reservoirs will have to be constructed, and from which water will be abstracted.

"The arrangement for water compensation to the streams and to those interested in the water, is proposed to be on the same principle as that on which nearly all such claims have been adjusted in all the great waterworks of the kingdom."

By giving a certain definite proportion of the ascertained or assumed available fall of rain, varying in quantity according to the peculiar circumstances of the streams affected, but generally about one-third of the whole amount in the manufacturing districts, where the water is largely utilized, the dry weather volume, or what may be called the useful working flow of water, is materially increased, to the advantage of those interested. The reservoirs are filled from the flood waters, which run uselessly and often mischievously to waste. These flood waters form by far the larger portion of the water flowing from a mountain district.

The districts which have been selected are free from metalli-

ferous runs, and from other sources of contamination. They are situated on the Upper and Lower Silurian formations, which yield water as pure in quality as that of Loch Katrine, and which afford sites for magnificent reservoirs, which may be constructed with perfect safety and facility, and of sufficient capacity to economize the full annual rainfall assumed, and to last out droughts of from 140 to 150 days' duration.

One of the districts is 66,000 acres in area, and situate a little to the east of the range of mountains of which Cader Idris and Aran Mowddy are the highest, being 2914 feet and 2979 feet in height. This forms the drainage ground of the rivers Banw and Vyrnwy, which join the Severn about halfway betwixt Welshpool and Shrewsbury.

The other district is of about equal area, and is situated on the east of Plynlimmon, which is 2500 feet in height, and forms the drainage ground of the upper portion of the Severn river proper.

The Bushey meadows in the valley of the Colne, are situate about three-quarters of a mile north-east of Watford, and are surrounded on the north, north-west, west, and south-west by almost bare chalk hills, varying from 500 to 900 feet in altitude.

The chalk formation in connexion with these hills appears at a short distance below the ground at Bushey meadows, and here as well as at many other points along the valley of the Colne, are found, at a depth varying from 100 to 200 feet beneath the surface, large faults, fissures, or cavities, varying from 12 inches to several feet in depth.

It is particularly deserving of notice, that in boring in the chalk formation, the approach to these fissures is indicated by the hardness of the chalk, which for a short distance before reaching them is like rock. On this being reached, the boring tool suddenly descends in the cavity charged with water. Exactly the same observations have been made on the chalk in Surrey.

It is a characteristic of the chalk formation, when slightly covered with a porous soil, that the heaviest rains are rapidly absorbed.

A portion of this water is consumed by evaporation, and in supporting vegetation; another portion percolates through the surface, and gradually gravitates, until, upheld by the density or impervious character of particular beds of chalk, it accumulates in the interstices which abound in various directions, and is conducted along the beds, until it oozes out from the sides of the hills, or bottoms of the valleys, in the form of springs, which uniting together, with the surface drainage, produce streams or rivers.

These springs from the chalk formation, as also from limestone formations under similar conditions, as we have noticed in the lias, are often of a very powerful character, and yield large quantities of very fine water.

The springs of Amwell and Chadwell, near Ware, in Hertfordshire, are of this origin, and from them the New River Company derives a partial supply.

The porous rocky chalks are excellent conductors of water, where they have only a thin covering of absorbent materials, as they imbibe, after the surface soil has been saturated, every particle of water that may come upon them. This is seen to be the case in many hilly situations, formed chiefly of such materials, in the south-west parts of the kingdom, as in the counties of Wiltshire and Dorsetshire. The water which is absorbed and taken up by so porous a material as chalk, soon escapes the power of evaporation, and continues to descend, in the manner of that which passes through a filtering stone, until it meets with an impervious or non-conducting stratum or layer, upon which it collects. If this collecting surface should be above the level of the sea, or other collection of water, it forces its way out in the manner of a spring or more copious fountain; not always in one constant stream, but often periodically. The springs of the chalk hills differ in this respect from those of the more open conducting kind of rocks; which is a fact that is entitled to be more fully investigated.

The action or operation of waters from chalk hills, is most clearly seen on the sea coasts, where the bases of the chalk cliffs rest upon an impervious or non-conducting stratum, which being softened and worn away by the impression of the waters collected upon it, the cliffs are undermined, and the faces of them are thrown down.

Where the base of the chalk dips beneath the surface of the sea in low tides, the whole collection of water regains its native home unseen. It is not doubted that much rain water, passing through other strata, finds its way to the sea in a somewhat similar manner.

The following experimental information on the subject of chalk has been furnished by Mr. Paten:

"I shall commence by describing some experiments carried out in the valley of the Colne. Twenty small borings driven at different portions of this valley, (about two miles in length, and three-quarters of a mile in breadth,) proved that almost any quantity of water was obtainable.

One of these borings, in the upper part of the valley, only five inches and a half in diameter, and 130 feet deep, was found to

yield 200,000 gallons per day of 24 hours, and one of 12 inches in diameter, 134 feet deep, in the lower part, yielded upwards of 600,000 gallons per 24 hours, shewing that the quantity obtainable was regulated by the size of the boring.

A shaft 12 feet 6 inches in diameter, and 34 feet deep, penetrating only 8 feet in the chalk springs, with four small borings in the bottom of 5 inches in diameter and 130 feet deep, had raised from it 1,800,000 gallons per day without exhausting the water; and I am sure if the engines had been sufficiently powerful this well would have produced double that quantity.

In boring through the chalk in the valley of the Colne, various beds of hard chalk-like rock are encountered. These vary in thickness from 12 inches to 8 feet, and below them are found large fissures, or cavities, from 12 inches to 12 feet deep, strongly charged with water.

As a precaution to prevent the tool, with the immense weight of rods, falling to the bottom of these fissures, when breaking through the rock, the men have a check rope regulating the fall to about 6 six inches.

To ascertain the depth of water below these rocks, or, as the well borers call them, "pans," I have had the rods lowered, and found the depth of water to vary, as I have said, from 12 inches to 12 feet. The pressure of the water, when many of the rocks are perforated, is so great that the chisel and rods can be turned round by the most trifling power, although it previously required great leverage to move them.

I have made borings higher up in the chalk ridge, and have not found these rocks; but even there a large quantity of water has been obtainable from fissures in the chalk, although by far the greatest quantity is procured in the valley below these rocks. This, however, is nothing new; all practical men are acquainted with it.

I know a person who bored in the salt marshes at Woodbridge, in Essex, to a depth of 200 feet, when the boring rods came to a sheet of water 18 feet deep. The same person made a boring for the parish authorities of Wickstead, in the same county, 380 feet deep, and met with a bed of water 20 feet in depth."

These fissures have also been found by M. Arago at St. Omer, in France, where he states five distinct sheets of water were intersecting one boring, and from each a supply was obtained. In the third water-bearing stratum, at the depth of 150 feet, the auger dropped a considerable depth, when the water ascended in a great volume. M. Arago also mentions an artesian well at Fontainebleau, where the boring rods, all at once, as in Essex, descended nearly 28 feet, and when it was attempted to withdraw

them, it was evident they were suspended in a body of water having so strong a current as to make the instrument diverge from the vertical direction. Five distinct sheets of water were intercepted in one well.

The absorption of water by the chalk upper stratum is very rapidly effected. It not only carries down the whole of the rain reaching its surface through a porous soil, but when covered by a retentive clay it is often used to effect the drainage of large areas of land.

In Hertfordshire, if a pit be sunk 20 or 30 feet in depth, in the middle of a field, through the red, flinty, and impervious clay of the county, into the chalk below; when the usual quantity of chalk is taken out, and the pit shaft filled up with the flints which are collected out of the chalk and clay, the top or surface drainage of this part of the field is much shortened for ever afterwards by making principal drains from the part of the field above the level of the top of the pit terminate therein; the super-abundant moisture will escape through the flints in the pit shaft to the chalk below.

The late Robert Stephenson made the following observations relating to the chalk formation on the subject of water:—

"It is almost needless I should inform you, that of the water which descends as dew or rain upon the surface of the London clay, little, if any, can be considered as absorbed into the earth; and that whilst a part again reascends into the atmosphere as vapour, or enters into the composition of animal or vegetable bodies, by far the greater portion flows off into the main drain of the district, the river Thames.

In this respect there is a most material difference from that portion of the surface where the chalk comes to light divested of any covering which could intercept the passage of the moisture. Being not only extremely porous, but also full of fissures in every direction, a very rapid absorption takes place, and we accordingly find that there are but few streams carrying off the surplus surface water, and that these are insignificant, and indeed many of them dry during a great part of the year.

The rapidity with which water finds its way into the bowels of the earth also prevents, in a great measure, evaporation; and we are therefore justified in assuming that the quantity which descends upon the surface of the chalk finds its way, with very slight diminution, into the fissures below.

The lower beds of the cretaceous groups, and the fault which immediately succeeds it, again present an impermeable stratum of clay, causing the water to accumulate through the lower regions of the more porous chalk.

An enormous natural reservoir has thus been formed, and the level up to which it may be considered as quite full of water is the lowest point where it can find a vent and overflow; therefore as the chalk communicates under the coast of Norfolk, Suffolk, and Essex, with the ocean, this level in the present case may be considered to be the same as the mean height of the sea."

These observations are confirmed in the vicinities of Brighton, Dover, Weymouth, and many places on the coast, where the chalk formation abounds, and where large quantities of fresh water are constantly discharged from the chalk into the sea.

The Brighton Water Company has been known to raise large quantities of water for the purpose of watering roads. A well was sunk in the chalk, about 11 feet in diameter, with four adits at the bottom, each about 2 yards square and 18 yards long; the adits were about on a level with low-water mark. A million of gallons per day have been raised from this well, and since it was sunk, the fissures in the chalk leading to the well have considerably increased in size, and the well in consequence capable of yielding much more water than when first made.

The level of the water in this well varies from 40 to 50 feet in the course of the year, being sometimes as much as 63 feet above high-water mark, and at others only 13 feet above this level: it is usually lowest in November and December.

In the neighbourhood of Brighton the rainfall is so rapidly absorbed, that no drains or watercourses are required to carry off the heaviest falls, and fresh water may at all times be traced at the bottom of the shingle at low tide, percolating through the beach.

At Lulworth Cove, a natural basin about nine miles from Weymouth, a large body of fresh water may be seen at low tide running into the sea, through the shingle along the coast.

Near the same place, a fine spring issues from the chalk, at about an elevation of 20 feet above high water, and turns an overshot water-wheel. There are besides many other powerful springs issuing from the chalk a short distance inland. Four miles from Weymouth is the Upway Spring, which is thus described: "Behind a semicircle of poplars, and at the other end of the village, is the Upway Spring. A low stone wall, at the foot of the hill, marks its very retired position. This spring usually rises 3 feet above the ground, and appears like boiling water; but in wet seasons of the year it becomes a large fountain, rising considerably above the surface of the stream."

Between Dover and Folkestone, water may be observed percolating at the bottom of the shingle from the cliffs, especially in the railway cutting leading to the Martello tunnel. There is

likewise a celebrated spring, known as Lydden Spout, which discharges a body of water at an elevation of about 20 feet above high water, through a fissure in the chalk cliffs.

At Dover, the level of the water in many of the wells varies with the tide. There is a well in Limekiln Street in which the water is 13 feet higher at high tide than at low water; it is never brackish, or affected by the sea, which it may be supposed arises from the rapidity with which fresh water is discharged from the high grounds to the coast. There are, however, wells in the lower part of the town which are occasionally brackish during very high tides.

The Cornwell station of the coast-guard is situated on the cliff, to the eastward of Dover Castle, about 400 feet above the level of the sea. A zigzag path has been made down the face of the cliff to the coast, and all the water required for the domestic use of the coast-guard station is fetched from a spring issuing from a rock which is under water at high tide. This spot is known to the sailors on the coast by the name of Cobler's Rock, and water is obtained from it at low tide, and carried up to the station in small casks slung over the back of a donkey which has been trained to go up and down the path.

At St. Margaret's Bay, situated between Deal and Dover, a large body of fresh water is known to issue from below a reef of rocks which is only uncovered at low water.

At Dover Castle there is a well 320 feet deep, at the bottom of which the current of water towards the sea may be plainly seen.

Mr. Homersham proposed to bring a large quantity of water from the Colne Valley to London. It was proposed to sink a well, or wells, into and drive adits through the chalk formation under Bushey meadows, for the purpose of intercepting and tapping the fissures above described; and it was anticipated that a very large quantity of water might with facility be procured in this manner from a very small area; there could be no doubt of this from the fact that a well sunk at Bushey meadows supplied the surprising quantity above mentioned of 1,800,000 gallons per diem. It was certain, however, that large manufacturers having mills upon the river Colne, and other streams in the locality, bored holes through the chalk, to pierce the fissures above referred to, and that they obtained considerable quantities of water for manufacturing purposes. One extensive mill owner and paper manufacturer at each of four different mills sunk a small-bore hole, 8 inches in diameter, into the chalk fissures, and derived in this manner a supply, always pellucid, and never failing, equal nearly to two millions of gallons per day.

The New River Company has sunk wells into the chalk formation at Amwell and Chadwell, and in seasons when "the yields of the several ancient sources of the New River are unequal to the demand in London, the additional supply is derived from what are usually termed artesian wells, sunk in the chalk, and situated at or near Chadwell and Amwell in Hertfordshire."

The area of the chalk formation in the South of England, almost bare or slightly covered by porous material, consists of 4117 square miles. The average annual depth of rainfall on this chalk district will be certainly under rather than over rated at 20 inches. Allowing that as much as one-half of this quantity finds its way to rivers, or is consumed in evaporation and supporting vegetation, still 10 inches depth remains to be accounted for and to percolate through the chalk, till, arrested by the impervious clay beneath, it accumulates in fissures or pans, to such a height as to occasion sufficient hydrostatic pressure to cause its exit by subterranean channels to the sea.

Now $(4117 \times 10 \times 2323200 \times 6{\cdot}25) \div 365$, equal to upwards of 1637 millions of gallons for every day in the year finding their way to the sea.

Water procured from deep wells in the chalk may be considered free from organic matter, but it is unquestionably hard water. When first raised from the wells it is about 17½ degrees of hardness, according to Dr. Clark's test; but after being exposed in reservoirs for eleven or twelve days, it parts with portions of carbonic acid which enables it to hold lime in solution, and falls to 14 or 15 degrees of hardness, which is rather less than the average of the Thames water supplied to London.

On the subject of the purity and quality of this water, the well-known Dr. Clark wrote the following letter to Mr. Homersham, at the time when the latter was engaged in the project of supplying this water to London:

"I have made a careful preliminary examination of the Watford spring water. I wish still to examine the water in some additional particulars, as well as to verify some of the results that I have already obtained; and I hope at a future period to send you a more ample and formal report; but in the meantime it may be satisfactory to you to be aware of the principal conclusions I have arrived at.

"The water appeared to me to be of an excellent quality of spring water. Under examination, it manifested the character of being singularly free from organic matter. The water is 17½ degrees of hardness.

"Each degree of hardness stands for as much hardness as would be produced by dissolving one grain of chalk in a gallon of dis-

tilled water by means of carbonic acid, sulphuric or any other acid.

"Minute numerical results I will give afterwards; meanwhile I may mention that all the above 17½ degrees of hardness are due to salts of lime; of which almost the whole consist of chalk (*i.e.* carbonate of lime, an alkaline salt), held in solution in the form of bicarbonate of lime.

"In addition to these salts of lime, amounting to 17½ degrees of hardness, the water contains a small quantity of magnesian salts; but these in the presence of so much lime do not destroy soap, although they make the soap that the lime destroys a little curdy; but any change that would bring the lime down below 10 or 12 degrees of hardness would bring this magnesian portion into action upon the soap.

"None of the other salts present in the water affect its hardness.

"A hundred gallons of the water, as it comes from the spring, require 36 oz. of curd soap in order to form a lather.

"The water seems to contain a very little uncombined carbonic acid, or of any other gas.

"Exposure to the air has the effect of softening it. In order to ascertain at what rate, I put about three inches depth of it into a circular green glass vessel, made for dairy use, which widened towards the top. The average diameter was about 12½ inches. At least half of the water was used up in making successive trials upon it during a period of three weeks. Thus exposed, I found the water to soften at the rate of about a quarter of a degree per day, and also to require for producing a lather with 100 gallons of it about three ounces less of curd soap at the end of each week.

"Filtration applied to this water would be a superfluous process.

"I tried upon it the effect of the lime-softening process. For this purpose, part of the water was converted into lime water by the addition of slacked lime; two measures of this lime water were mixed with 19 measures of the water itself. The two clear waters became perfectly white, from deposited chalk, like a weak whitewash; but within six hours the mixture seemed to clear very well. Tried at the end of 24 hours, the hardness was only 3¼ instead of 17½.

"At the end of other five days, the hardness was only 3 degrees. In 100 gallons of the softened water a lather could be formed with 7 ounces of curd soap.

"I have not met with any water that answers the lime process of softening better than the Watford spring water.

"All the waters within reach of London, so far as they have been examined by other chemists, or by myself, appear to be naturally of one quality; they are all chalk waters, differing by about four or five grains per gallon in the saline matter that they contain: but all with nearly the same kind of saline matter.

"This Watford spring water is of the same kind, only it has the advantage of being a spring water instead of from a river; just as if, instead of deriving your supply from the Thames, you took it from one of the uncontaminated springs that feed the Thames. I say that the saline matter in the Watford spring water is of the same kind as the river water contains; meaning that it is of a very different kind from what is found in the deep-spring waters below the London clay, commonly, however erroneously, called artesian-well waters; respecting which, as the only considerable source of supply of another quality of water within reach of London, I will make a brief notice.

"In the deep-spring waters alluded to there is a large quantity of bicarbonate of soda; 28 and one-third grains per gallon, according to the recent analysis in the Royal College of Chemistry upon the water of Trafalgar Square.

"There are also *other* 51·3 grains of saline matter present; say 79½ grains per gallon in all. When boiled, this bicarbonate of soda is reduced to carbonate of soda, and its alkaline taste may then be easily recognised in the water.

"A solution of carbonate or bicarbonate of soda, of this strength, will act medicinally on the kidneys. By calculation from the analysis alluded to, the hardness of the 'artesian' water is 5·9 degrees, which nearly agrees with my own experiments in this and other deep waters in London; 100 gallons of it would form a lather with 13 ounces of curd soap."

This letter not only explains very satisfactorily qualities and the hardness of chalk water, but it also elucidates the character of the water-test known as Dr. Clark's.

This test is a mode of estimating the hardness of water by the proportion of soap which it renders insoluble. By one degree of hardness according to this test, it is meant that the water possesses as much hardness as would be imparted by so many grains of carbonate of lime; for instance, one degree of hardness means that degree of hardness which would be imparted by one grain of carbonate of lime in a gallon of distilled water.

It does not follow that the waters do actually contain the proportion of lime indicated by the particular degree of hardness; but they have such a degree of hardness as would be imparted to them if they contained such quantity of carbonate of lime.

We may here refer to another description of impurity found in

water, though under very different conditions, because we may not have another opportunity of doing so.

This impurity arises from the effects of peaty soils upon waters which may be otherwise unobjectionable, and sometimes indeed of a very superior character for particular purposes. It has been observed that the peaty matter is more or less soluble in certain seasons of the year, and from certain peat bogs.

When the sun warms the ground, a quantity of salts of ammonia are formed, which are compounds of ammonia with an acid. When the ammonia is in excess, which happens in warm weather, the peaty matter becomes soluble, and the streams are often then made very brown, when flowing off some peaty ground.

When the cold weather commences, the matter becomes insoluble, and the purest water may then be squeezed out of the peat. It depends very much on the district, whether the peaty matter shall be found soluble or the reverse. In low districts, that is at low levels, the matter is very often soluble in warm summer weather, but it is frequently different in water flowing off peaty districts which are at a high level.

Undissolved particles are of no consequence; they do not affect the water; they soon become a sediment when the water is stored for a short time.

Very objectionable water may be obtained by digging holes in a bog from which the surface water might otherwise be flowing off quite pure.

Cold spring waters coming down on waters polluted by peaty matter will clear it, by causing the peaty matter to become precipitated. In the Belmont reservoirs the water was said to be sometimes quite brown and even thick, but the streams flowing from it, near Bolton, some few miles off, were not so. In this case it was supposed that the ammonia evaporated during the flow of the stream, and that the acids which are insoluble were precipitated.

Warmth is necessary to enable water to take up organic matter in solution, and the heat acquired by streams in summer favours the putrefaction of any organic matter flowing in the water. The amount of organic matter, of any description, dissolved by flowing water is very much greater in summer and autumn than during the other seasons of the year; this is peculiarly the case during exceptionally hot summers. In cold frosty weather there will be, comparatively, but little dissolved organic matter in streams and rivers.

The following may perhaps be taken as the average mean temperature of the Thames at different seasons of the year. At

the end of March, the temperature by day was 39·3 degrees, and 37 degrees by night, being 2·4 degrees warmer than the air. In the quarter ending June the 30th, it was 60·7 degrees by day, and 59·6 degrees by night, or on an average 3·6 degrees warmer than the air. For the quarter ending September the 30th, it was 63 degrees by day, and 92 by night, or averaging 3·9 degrees warmer than the air. For the quarter ending December 31st, the temperature was 47·5 by day, and 45·8 by night, averaging the same as that of the air. The observations are those of Mr. Glaisher, of the Royal Observatory. It is in the height of summer, when the waters of rivers are warm, that organic matter of every description becomes freely dissolved and chemically absorbed. It is in proportion to the warmth of the water, and the length of time of immersion, that the degree of putrefaction and absorption of organic matter by water may be estimated. Considerable proportions of the organic matter disappear as soon as the water freezes.

It is not necessary to insist on the importance of pure water for domestic purposes; the necessity is so self-evident, and all possible knowledge and information on the subject are so essentially requisite to the engineer, that we trust we need not apologize for introducing matter relating thereto, as well as the latest authentic instructions.

We shall first mention some of the evidence given this year on the subject of the application to Parliament for the East London Waterworks. It divulges a state of things apparently incredible, but well proved. We shall only mention such matters as were admitted on all sides.

Whitwell is a place where privies hang over the water, and in Welwyn the whole of the sewage runs in. To a certain extent, also, the river is polluted by sheep-washing, which is carried on upon a large scale. The preparation for dipping sheep contains arsenic.

The general drainage of the town of Ware passes into the sea, and upwards of 220 waterclosets, as well as household drainage, are discharged into the sewers. This sewage, without any liming or other sort of treatment, is passed direct into the river by several outlets.

The principal town on the river Stort is Bishop's Stortford: drains are general throughout this town, though the main sewers have not been laid down on any proper system; these drains receive and discharge into the river the refuse sewage of the streets, houses, and other places, as also the contents of upwards of 300 waterclosets.

Arriving at the lower end of the town, the sight witnessed was

sickening. The river was covered by large masses of black filth, which I believe is only to be found in open sewers. It is generated at the bottom, and when a certain period of its growth is reached it appears to obtain greater buoyancy; its hold upon the mud is relaxed, and it rises to the surface. The whole town, a considerable one, is drained directly into the river. Long rows of privies overhang the banks, large masses of excrement, in many cases not less than half a ton, are sliding into the water, the lower part being washed away, and the weight above constantly pressing down that below, to become mingled with the water. I do not at all exaggerate, when I say that the water in the river is quite as bad, or really worse than that in the high level sewer which drains the northern portion of London. The pollution of the water at Bishop's Stortford is not disputed.

Your committee found from personal inspection that the water before it reached the filtering beds was polluted in a most disgusting and abominable manner by drainage from land, overflow from cesspools, privies, factories, piggeries, &c., from the towns and places just before mentioned.

The water of the East London Waterworks Company is polluted to a very large degree by the drainage of the towns and villages upon the banks of the river Lea, from whence they draw their supply. An abundant quantity of water, even of the character at present supplied, was not to be obtained in the summer, without storing it for several months in open ponds. Lastly, pure water in sufficient quantity for the present and probable future wants of the district, cannot be obtained from the present source of supply at all.

The Company's engineer did not admit the *last* conclusion. He admitted that within the area of the river Lea there were sources of pollution, as upon all rivers, and the object of a proposed intercepting sewer was to remedy the most glaring defects and impurities in the river, but this was abandoned on account of the opposition from the Board of Works.

We are, however, in noways partisans as to any particular scheme, and as our only object now is to collect information, we will give the opinions on this subject of Dr. Letheby, confirmed by those of Dr. Odling, lecturer on chemistry at St. Bartholomew's Hospital, by Mr. Abel, Vice-President of the Chemical Society, and Director of the chemical establishments of the War Department, and also to a considerable extent by Dr. Frankland.

The East London water is supplied to the laboratory of the London Hospital; with very rare exceptions it is delivered bright and colourless from the mains.

"I have had samples from the reservoir at Lea Bridge, and I

have taken samples myself from the London main; I have compared them every month during the last six years. The water as delivered in the hospital main is in a purer condition than that which I took from the Lea Bridge reservoir. That is the case with water supplied by every one of the London Companies. The water in the act of passing along the mains loses a certain portion of organic matter, and also a certain portion of carbonate of lime; and therefore the water which I get from the public mains is always a little better in quality than that which I get at the reservoirs of every one of the companies."

"I regard the East London water as very good water for domestic consumption. There is nothing whatsoever, as far as chemical evidence or chemical analysis can go, to discover anything at all in it which renders it unfit for public use. The quantity of organic matter is small; it amounted upon the average to one grain in the gallon in the water from the reservoir, and in the water from the main it amounts to about 0·99 of a grain. But that represents more than the organic matter; it represents other things which are driven off by the process which we call incineration, or the application of heat; and I may say, relying upon the test of permanganate of potash, not one-half of that is organic matter. There is no absolute process known to chemists which will expose the actual quantity and real proportion of organic matter in water. We are obliged to rely upon two processes; one is called the process of incineration, and the other is the permanganate of potash. I took both of them. In the incineration process, you evaporate all the water and examine the residuum; and if the residuum is not perfectly dried by the process of submitting it to red heat, water will go off, and that is put down as organic matter. I use that test in the first instance. I also submitted some of the water to the other test, by means of permanganate of potash. I am alone in that mode of estimating the quantity of organic matter; but in determining the relative proportions I am not alone. I believe that every chemist who has had any large experience in the analysis of water, relies almost entirely upon the permanganate of potash test as evidence of the relative proportions of organic matter. I go a little further, and rely upon my experience in making it evidence of the absolute proportion; but I stand alone in that respect. I have obtained an empirical standard founded entirely upon my own experience."

"As far as I know, every water analyst in England, but one, agrees with me that permanganate of potash is a good test of the relative quantity of organic matter in water. Dr. Frankland does not agree with me. I can make an experiment, if it is at all a matter of interest to the committee to see how the experiment

is made; to-morrow I am to endeavour to satisfy Capt. Tyler that I took a correct view of this matter. I do not believe there is any real difference in our mode of investigation up to certain points; and then comes the question as to whether that empirical formula is the right one."

"I stated that the organic matter is not large for any domestic water; it has been determined by incineration only, and it therefore represents the maximum, or, as I call it, the exaggerated proportion. Unless waters are derived from wells near to the seashore, the chloride of sodium, or common salt, which is a very large constituent of sewage and of urine, is always a very good exponent of the quality of water. The quantity of chloride of sodium per gallon is small. It is below the average of the water supplied to towns, and of the running rivers of England. It amounts to only two grains in one case; and 1·7 grain is above the average proportion of it."

"I have examined the water of the company at Old Ford, Lea Bridge, and at Walthamstow, repeatedly, and I have traced the course of the river from the works at Higham Hill to Hertford and to Bishop's Stortford. Those works seem to be well adapted for the purpose of purifying the water. In the first place, they have a very large stowage or subsiding reservoir at Walthamstow, and as I am informed and believe from the area of them they hold nine days' water. Therefore there is nine days' aeration of the water, and subsidence, whereby all or most of the organic impurities of the water will subside, and then there is a run of about 1½ mile to Lea Bridge, where the water undergoes filtration through sand filters. I have seen these filters in operation, and they are constructed in accordance with the most approved plans, and they filter the water very well. It is not the case that filtering through a well-constructed sand filter only removes the impurities which are held in suspension in the water. The suspended impurities rest upon the top of the filter, but we know that the water in traversing the sand loses a portion of its carbonate of lime, and the sand possesses the power of causing a more rapid oxidation of the organic matter than would take place otherwise. The water, therefore, flowing out of a sand filter is always less charged with solid matter, and less charged with organic matter going into the filter, quite irrespective of that which is merely floating on the surface. I have a table which shows the condition of all the London water before and after filtration, and there is no doubt of the removal of it. I have made the experiment so often, that I have no doubt about it. I have examined the comparative purity of the water at Lea Bridge and at the hospital main, and ascertained that there is

no impurity coming into the water after it has been filtered at Lea Bridge. The water has improved and not deteriorated in quality. And therefore I say that nothing can come into it of any moment from the time of its delivery into the main.

"I was present I believe at Old Ford, on the 24th of February, when the covered reservoirs were emptied at the request of Capt. Tyler. I have a sample taken from the reservoir at the end of the pumping operation: there is no organic matter in it. There was some water found spurting on one side of the covered reservoir, which I analysed: the results are given in the following table":—

	Water from Reservoir at the end of pumping operation.	Water spurting from well of reservoir.	Water spurting from slope at north end.	Water taken from hospital main.
Total solid matter per gallon .	22·5	30·0	24·9	22·75
Of which organic and other matter lost by incineration	3·3	3·4	2·5	2·5
Organic matter, as estimated by amount of oxygen required to oxidise . . .	1·28	1·12	0·56	0·80
	Degrees.	Degrees.	Degrees.	Degrees.
Hardness before boiling . .	14·5	16·5	15·5	13·5
Ditto after ditto . .	4·0	8·5	5·0	5·0

There is always a greater amount of solid matter per gallon of water during the wet months of the year. That is so, we believe, with regard to every river. The organic and other volatile matters do not vary so much, but that is true, to some extent, of the organic matter. The organic matter is the thing to be looked to chiefly for each impurity. In November and December that is greater than in any other times of the year. The floods in the autumn sweep the surface of the land, after everything has withered and decayed which has been growing on the surface; and another reason why we find the organic matter to be larger in quantity in the winter months than in the summer months, is that the process of oxidation and decomposition is not going on in the cold weather, and therefore there is more of that in the winter than in the summer time.

It is remarked that with most if not all the rivers of England, after a run of 18 or 20 miles, or even less than that, it is not possible to discover by chemical means a trace of sewage in the water. For instance, between Coventry and Warwick all the sewage is discharged into the river, and at Warwick they are taking it for the town supply; and at the time we examined it we

could not by any chemical analysis find a trace of sewage in the water. The heavier matters very rapidly subside; in the next place, the matters are capable of undergoing oxidation, or of being eaten by the fish, and plants are very greedy in taking up all that is in solution, and then there comes the power of atmospheric oxidation: so that between all these operating circumstances the sewage is quickly gone. The distance from Coventry to Warwick is about nine or ten miles.

"At the present time you cannot discover the sewage in a run of 20 miles. From Bishop's Stortford, where the river is so foul as really to alarm one, I was told by the man at the mill a mile and a half below Bishop's Stortford that he could hardly live there in summer time; and yet in a run of 20 miles the sewage cannot be discovered by chemical analysis."

We do not at the present moment understand the immediate agents of disease. In all probability they are living germs; it is quite possible, though it is not probable, that a living germ might live in the water when other things would go, and those minute germs are not discoverable by the microscope, or by any chemical process; therefore it is just possible, though there is no evidence of the probability. The chemist cannot discover choleraic poison; the chemist supposes it to be there, and he cannot discover it. There is no test to apply to discover its presence; it might be there, and we could not detect it.

If we are to use the water of a river for drinking purposes, it is not desirable, or a proper thing, that the rivers should be, notwithstanding their self-purifying powers, the receptacles of sewage. "I have said it was possible that deleterious matters may remain in water which has been polluted by sewage, although it cannot be discovered chemically; but it does not appear to me that is very probable, because it is only assuming one condition of things of which we know nothing; and that is, that the agent of these special zymotic diseases, as they are termed, is a living thing. If those diseases are brought about by the action of putrefying matter on the human body, then I say that the putrefying matter cannot exist in running water for any distance; but if you assume that it is a living germ, then I say that it is possible that it may be in the water without being discovered."

The presence of the chloride of sodium is the only one on which we can rely to prove the existence of sewage in river water. As to organic matter, we do not know whence it comes, but the chloride of sodium must no doubt have had its origin in matters discharged from the animal body.

Sewage alone requires a very long time to undergo the process

of self-purification. The sewage discharged into the Stort at Bishop's Stortford does not render the water of the river in the condition of the sewage discharged at Barking Creek.

"We consider in the first place that sewage must be mixed with twenty times its bulk of good water in order to be in a condition to undergo oxidation; then a flow of nine miles will deodorise it, and make it so pure that I should not have the least hesitation in using it."

Without the mixture of twenty to one, it would probably want nine times twenty miles to run, or something like that. It is merely a question of degree; the atmosphere is not capable of doing an unlimited amount of work. If you only gave it space enough, the sewage of London would become perfectly pure water in time.

After running through a considerable distance, the first plants to grow in it would be the sewage fungus; they would effect a great purification. Then there would be the river ranunculus; then plants like watercresses; then the flags which you see growing on the river banks; and then the American weed; and we know step by step, as those plants make their appearance, what is the purity of the water; and in the end there would be nothing there.

It is said that the main sewage by Hackney is tapped by some of the watercress growers, and they let it run through the watercress beds; and when it comes out, it is so pure as to be fit for domestic purposes.

In the upper Thames, the river is sensibly purer after passing through a great mass of weeds, than after passing through a large town.

In the case of the Thames Companies, before filtration the hardness of the water is nearly 14·5 degrees of hardness, and after filtration 13·3. The New River, before filtration 15·5, after filtration 13·5. The East London water, unfiltered is 14·4, and filtered it is 14·0. The samples are average examinations, inasmuch as they were not all taken on the same day.

The Kent Waterworks Company's water is not filtered; it is drawn from the wells, and sent directly to the mains. It is hard water, but it is not filtered. It would not become softer to any great extent by filtration. It might in the same proportion as the New River water; perhaps the degree of hardness might be lessened by filtration. It is not necessary to filter water drawn from chalk wells for the purpose of removing organic matter.

The table shows the amount of organic matter removed from the water by filtration; organic matter being determined by the usual process of incineration of the solid residue; and it shows

this, that in the case of the Thames water, the organic matter is reduced from about 1·26 grain per gallon to 0·97; that in the case of the New River water, it is reduced from about seven-tenths of a grain per gallon to rather less than six-tenths; and in the case of the East London water, from nine-tenths to three-tenths of a grain. That is determined by incineration. We have also the result of boiling upon these several descriptions of water, as affecting their degrees of hardness. The Thames waters are reduced from 13 degrees of hardness, which is their state after filtration, to from 5·3 to 4·6 degrees. Taking the average, the primitive hardness of this water is 13·3, and the hardness after boiling for a quarter of an hour 4·6. East London water is reduced from 14 to 5 degrees of hardness, and the New River from 13½ to 4.

Ammonia is another indication of the quality of water, and the chemical tests show that the proportion of ammonia per gallon in the London waters is expressed by a third decimal place; it is 0·003. The rain water of rural districts has been found to contain considerably more ammonia than that.

Water from the clouds contains more ammonia than is found in the water which is supplied to the public of London; and if ammonia be evidence of the existence of putrefying matter, the fact of there being so small a quantity of it in the water supplied to London, would indicate the absence of decomposing organic substances. The rain water of the City of London contains nearly half a grain of ammonia per gallon. With regard to the quantity of saline matter which would make water unwholesome, there is evidence that at Carrara water may be drunk in considerable quantity which contained 92 grains of carbonate of lime per gallon, and there is at the present time no evidence at all as to the proportion of saline matter which would make water unwholesome.

Generally speaking, we say that a water containing more than 10 grains of carbonate of lime, or its equivalent, per gallon, is regarded as a hard water: but there is no evidence to justify an opinion at what point it becomes unwholesome. There is no evidence to show that the water at Tunbridge Wells is unwholesome, or unfit to drink in consequence of the presence of lime in it. The hardness of water may be due to magnesia to some extent, but it is chiefly due to lime.

The water of the Kent Company is so free from organic matter that when it is looked at in a long glass tube, it is nearly blue. It is like distilled water in that respect. The average amount of organic matter is about 0·2 of a grain; nevertheless it gives off

a good deal by incineration sometimes, but it is no indication of organic matter.

Animals, generally speaking, are not fond of water containing carbonate of lime; they will prefer drinking out of a dirty pool to drinking hard water. If we find an excess of chloride of sodium, it is generally a bad indication; but there are exceptions to that rule, because some waters which are in the neighbourhood of the sea-shore contain common salt to the extent of four or five grains, without being injurious or giving any indication of being polluted; but when we have common salt in rain waters in large quantities, or when we find common salt in well waters, we are disposed to think such common salt must have come from the secretions of the human body, the urine in all probability, and it is an indication to some extent of previous pollution. Common salt found in water, in small proportions, is in itself harmless, but it is an indication of the sort of matters which may have got into the stream.

The water of the Kent Company has more solid matter contained in it in the year 1867 than it had in the year 1856; but that is due to the fact that they abandoned the River Ravensbourne, and are now taking deep-well waters.

The town of Birmingham is supplied from the red sandstone formation; Guildford is supplied both from the chalk and the green sand; the water is 18½ degrees of hardness, as also the Leamington water. The Birmingham water contains the largest amount of solid matter per gallon, and is 15½ degrees of hardness; Loch Katrine contains the smallest proportion. Sheffield is supplied with very soft water, containing less than six grains per gallon. Edinburgh is peaty water, taken from the hills. Southport water is out of the red sandstone, and is 19½ degrees; the mortality in Southport is only 19 per 1000.

The question of the advantage of supplying a hard or a soft water to a town has been much considered, both in France and in Austria. A short time since it was referred to a commission of French chemists, whether a hard water or a soft water was best adapted for the supply of Paris. The commission rejected the soft water, and selected a water very similar in its composition to that now supplied to London.

The new Paris water is very similar to that of the New River. That is the water which has been selected by the commission appointed to inquire into the best source of supply for the French capital, in preference to a very soft water, which they might have obtained from a granite district. They selected it because they considered that the water supplied to a large city should possess certain qualities which a very soft water rarely or never possesses.

It came from chalk, just in the same manner as all the London water comes from chalk. The New River water and the Lea river water are in reality chalk waters, but they have become a little softer by passing through open channels. The new Paris water is brought from near Chalons-sur-Marne, which is a large chalk district. They expect to get a supply of thirty gallons per head.

At Vienna there has been a commission to inquire into the best water supply to be obtained. The commissioners have reported in favour of a rather hard water in preference, and they have made their report upon very nearly the same grounds as the French. They have examined and selected water of from 10 to 18 degrees of hardness, and they say that water of 12·6 degrees of hardness is not objectionable; and that it is of primary consideration, in supplying a city which uses the water for drinking purposes, that it should be bright and clear, and well aerated.

The general characteristics of a hard water, which render it the better adapted for the supply of a town, are these; it is generally bright and clear, and well aerated water; it is pleasant to the eye and grateful to the palate. In the next place, it is not supposed to absorb foul gases; it is generally so charged with gases, that it has little or no tendency to take in other gases. It is not liable to putrefaction, and the organic matter is small, and is better preserved in it than it would be in a very soft water.

It has no chemical action upon lead or iron pipes, which is another good property, for although soft waters may not acquire a poisonous property from being brought into contact with lead, yet we know unquestionably that soft waters do act upon lead. Though the waters supplied to London have a primitive hardness of 15½ degrees, yet when they are raised to the boiling point, the hardness falls to 11·2; by boiling for five minutes this hardness is reduced to 9·3; by boiling for a quarter-of-an-hour to 4·4; for half an hour to 2·6, and for an hour to 2·4. The chief objection to it is the crust which is deposited from time to time, but it is not adherent to any great extent and is easily removed. It differs very considerably in its texture and firmness from the crust formed from sulphate of lime on salinitic waters.

In the year 1851, Dr. Hofman, Dr. Miller, and Professor Graham reported that water containing 92 grains of carbonate of lime, and of from 30 to 90 degrees of hardness, might be taken without any injury to health; that represents the same proportion of carbonate of lime, or its equivalent, it may be sulphate, in the water.

The French commissioners also reported that a hard water

seemed more salubrious than a soft water; they came to the conclusion that hard waters were really beneficial; that fewer conscripts were rejected coming from a hard water district than from a soft water district, and they thought that the calcareous matter was probably food, and was necessary for the development of the tissues; that was a consideration which weighed very much with them in their selection of water for the city of Paris. Waters coming from a chalk and limestone district are more wholesome than waters coming from the clay; the waters coming from the clay are insipid and cold. They have not always fertilizing properties, and those they possess they owe to the presence of nitrates; and with regard to some of the lower green sand waters, which contain nitrates, confervæ grow in these waters almost immediately after their issuing from the sand.

Dr. Letheby had some practical opportunities of examining the state of the sand after the filtering process had gone on upon the works of some of the companies. He says, "at the time of our visit to the works of the companies, we made a very careful examination of the manner in which the water was filtered. We found that filtration was effected, generally speaking, through three feet of fine sand, and then through coarser sand, and I was curious to know not only from an analysis before filtration and after filtration, what was taken out of the water, but also by an analysis of the sand to ascertain whether it was practically an efficient agent for the purification of water, and I had samples of the sand taken from the filter beds, and the sand when washed and ready to be put back again.

The analysis of the sand and the experiment show that a very considerable portion of organic matter is taken from the water by the filtration of the water through the sand.

They have always reserve filter beds, and as soon as a filter bed gets what may be termed foul, and ceases perhaps to pass water as freely as it should, that bed is thrown out of use, and the foulness is found upon the immediate surface of the sand. That is taken off, going down to such a depth as the colours would indicate the presence of impurity, and it is then well washed, and is in a condition to go again into the filter, and to carry on the operation a second time.

After a time the sand breaks up, and it is an item of some importance in the expense of the water companies the renewing of this sand. There is a particular weed, which we call silt weed, which grows very rapidly upon the filter beds in the summer time, causing a difficulty in the filtration of water, and necessitating the cleansing of the beds more frequently than at other times. Indeed, if it were not that the matter were stopped at the very

surface of the sand, the filtration of 100 millions of gallons of water distributed in the metropolis would be almost impracticable. But the organic matters in suspension being stopped by the finer sand, when that is taken off and washed, the sand is restored to the state it was in, or very nearly so, when it was originally put down, excepting that it contains a little more carbonate of lime.

Dr. Frankland has made the following recommendation on the subject of filters. He strongly urges, that during the prevalence of cholera the whole of the water supplied to the metropolis should be passed through animal charcoal, immediately before transmission to consumers from the reservoirs of the respective companies. For this purpose, 300 tons of bone black, in the condition in which it is used by sugar refiners, would be required to purify the total supply of the metropolis; as "I find that water passed at the rate of 1,000,000 gallons in twenty-four hours through three tons of bone black is completely purified." This operation, even when performed upon the water supply of London, 100,000,000 gallons daily, would be neither formidable nor expensive. Three or four days would suffice to fix the necessary filtering boxes, whilst the animal charcoal, being an article which is now manufactured on a very large scale, can be had on the shortest notice. It is scarcely necessary to add that the water should be passed through the animal charcoal after it has gone through the usual process of filtration.

We must now make a few more observations on the quantities of water to be obtained from deep chalk wells, not so much perhaps on account of the supplies to be obtained by such means for very large towns, as for those of minor importance, or as auxiliary supplies for domestic consumption.

The Kent Waterworks Company began to use the chalk water in 1859, and they consider that at present they have double the quantity they require; they are raising from their wells 7 million gallons per day, and the wells have been pumped even to the extent of 14 million gallons per day. The principal well is at Deptford; it is sunk to the depth of 100 feet, and bored 170 feet in addition, and the water rises to 2 feet 6 inches above high-water mark. It does not vary in its flow.

When it gets to its maximum height, of course the flow is insignificant, but to pump from one well at the rate of 5 million gallons per day, it is necessary to lower that water from 70 to 80 feet. It is never found to decrease in dry summer weather.

They generally take from that well about 3 million gallons per day, at from 40 to 50 feet below Trinity high-water mark.

The second well is on the same premises, and is situated about 250 yards from the first. That well is not at all affected by the

pumping of the other, and from that they raise about 1,250,000 gallons per day. That may be considered as the maximum, because that well is kept going day and night.

The next well is No. 3, on the premises, again situated at a like distance from each other. They get from that well half a million or three quarters of a million gallons per diem. That is a very small well, a trial well in fact, and that may be considered as its maximum. There are also two wells at Charlton, on the lower level. They are about equal in capacity; they use them very little, but they can get three million gallons per day there. The depth of each well would be sunk 90 feet, and bored 150 feet more. In the largest they began with a 16-feet shaft, and sunk down a 14-feet shaft to the level of 100 feet. Then they bored an 18-inch bore hole; and in addition to that they drove galleries about 100 yards right and left at the bottom of the well. The galleries are driven in the solid chalk, and the chalk is in all those cases at the surface of the ground at this point.

There is a well at Plumstead, which is of a smaller character, which was formed by the Plumstead Company; it only yields about 500,000 gallons per day; that is situated on the upper level, but they have to go through some intermediate strata to get the water from the chalk, as in other cases.

They have lately sunk a well at Bromley, about three miles above, up the valley of the Ravensbourne. The present supply there is very small; they do not use this well above three hours per day, but they make scarcely any impression upon that well. They have not lowered it more than 10 or 11 feet. It is sunk about 95 feet, and in this case they have an overlying bed of sand about 70 feet thick, and they merely pass through that and pierce the chalk. They then bore about 100 feet lower, and the water rises to the surface of the ground, and there the ground is about 70 feet above the level of the Thames. They are only pumping a very small quantity of water there, not more than three or four hours a day. It is a new district: the water does not flow over the well, but stands within about 3 feet above the surface of the soil.

There is a well now in progress at Crayford, which has been tested, but not for supply. That well it is expected will perhaps yield more water than any of the others. The well itself is completed, and the machinery is also complete for distributing the water. It is believed that ten million gallons may be got there. There is no well at Shooter's Hill; that is merely an engine-house, with a second lift to pump the water up again to a higher level. That water comes from Deptford. Those are all the present sources of supply.

Those wells can be pumped, from actual pumping, to fourteen million gallons per day.

Since the relinquishment of the River Ravensbourne the company has expended as much as 198,000*l.* in the adaptation of the works—that is, upon their extension.

The district directly available extends about twenty miles along the North Kent Railway, between Blackheath and Higham, and includes, according to Mr. Ansted, the great geologist, about 180 square miles of country, consisting of chalk beds of great thickness, resting upon the Wealden Clay, which is very retentive of water. The chalk is said to be of a somewhat open texture, the surface broken by numerous fissures, and the mass of rocks to have many joints and faults.

Where those joints and fissures had been pointed out, the Kent Waterworks Company have sunk wells from time to time, and by those means have been able to obtain a very large supply of excellent water.

Mr. Ansted has found by experiment that chalk in this state and when fully saturated, contains about two gallons of water in every cubic foot of chalk.

It is now some years since, we believe in 1850, that Mr. P. Barlow called public attention to the fact that the whole rain which falls upon the district does not produce any surface stream, but appears to escape chiefly by subterraneous channels.

By the interception of the fissures and faults, or subterraneous channels, by means of artesian wells, the supply of water was obtained in great abundance.

The rain falling upon the downs and elevated ridges is rapidly absorbed by the soil, and enters the chalk beds, through the porous and simply aerated channels of which it circulates, much of it probably for centuries, before subsiding to the lower level of the valley springs. Hence a full decomposition of any alterable organic matter, and the assumption by the water of a constant and uniform character. These chalk-spring waters contain many of the qualities desirable in potable water. It contains absolutely nothing of organic origin, capable of further alteration or decomposition, and is therefore wholly unobjectionable on the ground of organic constituents. Its clearness and brilliancy also appear perfect, from the complete absence of suspended matter. Possessing at all seasons the mean temperature of the year, these waters have an agreeable coolness and freshness, which might certainly be preserved in a great degree by *proper means of conveyance and distribution.*

The Government Commissioners appointed in 1851 to inquire into the quality of the water supplied to the metropolis, reported

that the water recommended appears to approach most closely to the standard of all that is excellent in a town supply, and is worthy of the greatest efforts and greatest works to procure and convey it. But the sources are near at hand, and the water is attainable without any difficulty or great expense.

With such a noble application of the chalk-spring water in view as the supply of the metropolis, it would be a desecration to permit that water to be wasted on other uses, and most impolitic to allow the possession of it to pass into private hands. "It is our deliberate opinion, which we would enforce in the strongest terms, that the most desired and most necessary improvement in quality of the London water, is associated with the sources of supply, and will depend upon their proper application to the uses of the public."

We have ventured to lay considerable stress on what we consider the quality of chalk-spring waters as drinkable waters, because we are convinced that if they were properly conveyed and distributed they are equal at least to any waters that can be brought to London, and because we believe that at no distant date these waters, in conjunction with those proposed to be brought by Mr. Bateman from Wales, will form the principal portion of the London supply.

The city of Glasgow is supplied with some fifty gallons per day per head of the population, or nearly double of the London supply. Much of it is said to be *wasted*, which we may suppose means not sufficiently paid for. We cannot but think that the gigantic sewerage system of London would be benefited if twice or three times the present quantity of water passed through.

The final doom of the existing metropolis supply is simply a question of a few years, and probably depends on the advent and severity of the next epidemic of any unusual kind. It cannot be a mere question of cost. An enormous capital has been raised for the internal means of transit of this vast and rapidly increasing capital. When its population is made to feel a little more keenly all the importance of an abundantly large supply in regard to general cleanliness, on which health so much depends, we think they will be more alive to the subject, and will see that the water which they drink, and with which they wash and cook, is in reality quite as important as easy means of locomotion.

We readily admit that all the London water companies, as well as the able and eminent men by whom their undertakings are managed, have done all in their power, with existing means, to satisfy public necessities; but also, we believe that those means are exhausted.

We can see no valid reason why, for such a metropolis as London, increasing annually by some square miles and by hundreds of thousands of people, some of the great projects lately brought forward should not be acted upon; why a much more liberal supply should not be given for cleansing purposes, and for the watering roads, which is wanted more than badly enough.

The public, however, took so little interest in the subject when it was brought before a Committee of the House of Commons last summer, that the Committee could scarcely make any other report than that the supply was "so far satisfactory that there is no ground for disturbing the arrangements made under the Act of 1852."

In view of what has been said of the water supplied by the Kent Waterworks Company, and that supplied from the Lea,—of which a tributary, the Stort river, is, as admitted by the company's servants, covered by large masses of black filth only to be found in open sewers: generated at the bottom, when a certain portion of its growth is reached, it appears to obtain greater buoyancy; its hold upon the bottom is relaxed, and it rises to the surface; long rows of privies overhang the banks; large masses of excrement, in many cases not less than half a ton, are sliding into the river, &c. &c.,—it seems difficult to believe that one part of London is as well off in respect of water as another, and that the present state of supply is "satisfactory." The contents of the Stort may have to flow twenty-five miles or more before reaching the company's works; they may thereby be "purified," to the extent stated by Dr. Letheby, that under such condition he would not hesitate to "use it," though he does not say for what purpose; still it requires a great stretch of faith in science to believe that, even after any amount of filtration, it will be as wholesome and as pleasant to drink as the pure sparkling waters from the chalk wells in Kent, or the waters that flow off the spotless mountain sides of Wales. We have ourselves by means of peat charcoal, filtered very foul sewage until it appeared as clear as any London pipe water, and until it was perfectly free from smell; but we know also that shortly afterwards it became putrid.

We are much disposed to believe that ultimately there will be a double system of supply for London; that is, one set of pipes carrying drinking and cooking water, and another set conveying water for other purposes. Possibly this may not be until the public have expended a few more millions in unavailing attempts to improve that which is not to be improved, though perfectly effectual in damaging, perhaps irremediably, the channel and

navigation of the Thames; but it is one of those things which will have to be.

The following statement of Mr. Bateman's is built up of too many hard facts to be practically refuted:—

"Short as the period is since the completion of the various improvements and alterations they were called upon to make, several of the companies are already looking anxiously for additional means of supply; and though those companies which are enabled to draw water from the Thames have still a considerable margin left, it will be insufficient to meet the wants of many years. By the various Acts which were passed in 1852, authorizing the withdrawal of the water from the river, the maximum quantity which they were empowered to take was 100 million gallons per day, and there are, I believe, many days in which between 60,000,000 and 70,000,000 gallons per day are abstracted, although the average daily abstraction, including Sundays, does not amount to 60,000,000. It is notorious also that the volume of the Thames has been so diminished of late years, and has otherwise undergone such material changes, as to create a great anxiety in the minds of those interested in the maintenance of the river.

"When the Acts of 1852 were passed, it was estimated that the minimum quantity of water at Hampton was 362 million gallons per day, and this minimum has been habitually considered in round numbers as 400 million. During the month of September, 1865, the river has been carefully measured above the waterworks at Hampton, and the gross daily quantity has scarcely exceeded 300 million gallons. The residents on the banks of the river below the lowest point at which water is taken by the water companies, have this year been loud in their complaints of the diminution and pollution of the water, and have been holding public meetings for the purpose of seriously considering what steps are to be taken for maintaining the volume and purity of the stream."

Considering that the time of the year when the supply to the town must be greatest is that when the discharge of the river is least, it would seem that 100 million gallons, a third of the river discharge, is a large quantity to abstract in view of maintenance of the river channel.

On the subject of a double system of pipes in connexion with a supply of pure spring water for the purposes of drinking, the engineer of the New River Company observed that he thought that ten gallons per head would be a very good average and an ample supply for mere domestic purposes. The actual domestic consumption now, in the New River district, is between 22 and

32 gallons per head instead of ten, and great waste has taken place in private houses. When we add the trade and street consumption, it brings the number up to 28 or 29 gallons. Out of the 23 gallons a very small proportion is used for drinking and cooking purposes. Assuming that the water is not of a quality that some people might think fit for drinking, that would only apply to a very small percentage of the quantity supplied to a house.

But for the enormous cost of laying down duplicate pipes, the suggestion which has been thrown out for having a pure supply for other purposes, would be a very good one.

"I have made approximately an estimate of what duplicate lines of pipes of smaller diameter for delivery in the New River district of the smaller quantity of water which would be required for those drinking and cooking purposes would be, and made out something like 600,000*l.* for the New River district; including, however, I should say, which would be the chief part of the expense, a large main running into the country.

"Our supply last year on an average directly from Chadwell springs was 500 cubic feet per minute, or four and a half million gallons per day. That would be four millions out of twenty-three millions. I have no idea what proportion would be actually used for food and drink. I have allowed between five or six gallons per day, which would be very ample. For mere drink and food I do not believe it would reach two gallons per day. Our springs would supply the entire population with spring water in our districts, if we had a double population, without going to a new source; but it would be by bringing up the spring water which comes up from those deep chalk wells."

If necessary, they could therefore supply the whole of the district with pure spring water at an expense of 600,000*l.* There would be little or no obligation to constant supply, because the apparatus could all be supplied *de novo*. It was thought if any question arose as to the advantage of having any better water than that now delivered, they could meet the requirements of the "most philosophic, or chemical, or medical men" at an expense of 600,000*l.* from the present resources.

That estimate does not include the lead pipes or service pipes that would be led into the house. It is supposed that the owners of the houses would branch from the mains, with their new drinking supply for themselves, as they do at present.

The advantages from a constant supply would be felt chiefly in the houses of the poor, and the other advantage is the saving of the expense of a cistern in the case of new houses. If we do not allow that, the drawback of having no cisterns, and there-

fore no water, when the mains are off for repairs, is not a counterbalancing thing.

By the present intermittent system, every house is dependent upon the quantity of water which it receives in its cistern once a day. Those cisterns are often so placed as to contract a good deal of impurity.

It is supposed that this is pure spring water, and that the water of the Chadwell spring, and also the water of the deep chalk wells, which the company has gathered together into this main, is brought to London and branched out, so that the second supply might be given to houses, as from the existing mains. The second supply, for waterclosets and so forth, would still come from the Lea at Hertford. There was no definite plan at all upon the matter of two pipes; but the suggestion having been thrown out, that it might be possible to deliver water in London of a purer description, in smaller quantities, for drinking and cooking purposes, and a large supply of less pure water for waterclosets and ordinary use, the engineer to the company had turned the subject over in his mind, and estimated just what it would take to bring the New River to London, and branch it out in pipes into every street.

On the subject of the supply per head for actual domestic purposes, Mr. E. Easton states that he made the following experiments: "I have had an experiment made in my own house, which is near Russell Square, of a rental of 120*l.* per year, and one at a house where my brother lives in Montague Square, and at the house of a friend who lives in Euston Square. I took it for a week and measured the absolute contents of the cisterns, and how much was filled; the result of that experiment was, that at my own house we used every day 80 gallons, or 11 gallons and a little over per head. At my brother's house they used 102 gallons, or 11 gallons per head, counting four children as two adults. At the third house they used 11 gallons per head, but in that case there was a ball-cock out of order, and when the water came in there was a certain quantity of it wasted every day."

The following laconic sentence of Mr. Bateman's, coming from so eminent and practical an authority, throws much light on one of the questions we have to consider in all large towns in respect of water supply: What is waste?

In respect of the city of Glasgow, Mr. Bateman says: "I have done my best to arrest the waste there, but they have, as they suppose, an inexhaustible supply from Loch Katrine by gravitation. IT COSTS THEM NOTHING, IT WASHES THEIR SEWERS, AND IT SWEETENS THE CLYDE; AND THEREFORE THEY ALLOW IT TO EXIST!"

Who can blame them? Should we not be very happy to wash our sewers, which of necessity and inevitably must become more offensive every year as population increases and a larger area has to be cleansed? Should we not be desirous to sweeten the Thames? But there is a cost which deters, and the fear of which makes the existing arrangements "satisfactory."

If such is the opinion of a committee appointed to investigate, have we cause to be surprised that parish authorities, builders, and working classes scarcely see in what way and in what quarter they are to complain, however much the latter may be made to feel?

Possibly in a few years more the cost will have to be considered in a different manner and under a different aspect.

We may say that it is but the other day that Dr. Frankland deemed it necessary to make the following remarks upon one of the London supply reservoirs; at present the matter has been rectified, but London will always be liable to such occurrences, until the system of supply is entirely changed:—

"I was astonished to find that the water after being carefully brought down from Tottenham mills in a special canal, purified by a most elaborate and efficient system of filtration at Lea Bridge, and then to secure it from atmospheric impurities, conveyed in an iron main down to Old Ford, is stored in a reservoir, sunk to a depth of some 16 feet below the low ground, which is here only just above the levels of spring tides, and that when the reservoir is full the level of the surface of the water in it only reaches that of Trinity high-water mark. This reservoir, I was informed, is excavated in clay. The side next to the navigation branch of the foul river Lea is of gravel. No doubt this is well puddled and the brickwork sides executed in the best possible manner; nevertheless the position of this reservoir with its 2½ acres of floor, 16 feet below the surface of a badly drained district, is fraught with much peril during the prevalence of an epidemic disease."

CHAPTER II.

WATERWORKS.

Constant and Intermittent supplies—Specification of the Brighton supply—The Manchester, Newcastle, Edinburgh, Cambridge, Bristol, Carlisle, and Croydon supplies—The Intermittent and Constant systems.

In Brighton, arrangements were made for the supply under both systems, constant and intermittent, and for laying down mains for the constant service, without removing those supplying under the intermittent system.

If the water had been turned on immediately from the intermittent to the constant supply, the apparatus purchased from the old water company would not have been sufficient to have supplied the water required. At the present time there is a second pipe in every street in Brighton, so that the houses of many streets are supplied both on the constant and intermittent systems.

The arrangements in each house are—first of all as regards service pipes; they are to be made of strong lead pipes, half an inch, not less than 28 lbs. per 15-feet lengths, or in round numbers, a little less than 2 lbs. to the foot; and if $\frac{5}{8}$-inch pipes are used, which is not very often the case, they are 33 lbs. to the 15-foot length; $\frac{3}{4}$-inch pipes, 39 lbs. to the 15-foot length, and 1-inch pipe, 62 lbs. to the 15-foot length.

Then all pipes within the premises must be so exposed as to allow of immediate inspection; and no pipes are allowed to be placed under the floor, or buried, except when necessary to prevent freezing. All connexions must be made with stout plumber's joints; a strong high-pressure stop-tap is to be fixed on the service pipe where it enters the premises, and all taps supplied from the company's mains must be high pressure.

All cisterns are supplied with high-pressure ball-tap. A waste or warning pipe must be placed two inches below any air pipe to closets, and be so fixed that the overflow, if any, may be seen. No waste pipe is allowed to lead to a closet, drain, rainwater pipe, or any place that prevents the immediate discovery of the waste.

All closets (Coumin's high pressure excepted) must be supplied from cisterns with self-closing valve. There is a restriction about gutta percha hose. They do not make any distinction as to the self-closing valve, but they recommend Coumin's closet, which is the water-waste preventive.

All boilers or hot water apparatus must be supplied from cisterns, as in no case are they permitted to feed from the company's mains.

As to laying on water, all the pipes, taps, cisterns, closets, and other apparatus must be approved of by the inspector, and made complete before the connexion is made to the company's main. It is requested that persons intending to have the water laid on should previously call at the inspector's office, where all requisite information is to be supplied to them. These are the regulations which are set forth by the company, but there is considerable difficulty in persuading the directors to take the means which are necessary and in accordance with these regulations.

Experiments have been made to show the use of water in those cases where the system has been properly carried out, and other experiments showing where it has been partly carried out.

In the first place, there is a stop-cock always put between the main and the house on the communication pipe, at the most convenient point, sometimes inside and sometimes outside the house. A lead pipe of the specified weight is then attached, and in the case of the poorer houses, a big cock is fixed over a sink, or not, as the case may be. They are done in both ways, and in the case of a closet being put on, one of the self-acting closets, or Coumin's closet apparatus, is attached to the closet in the poor houses.

The tap is generally in the house, when the house itself is supplied. But in very many instances that is not the case. They have a very poor population in some parts of Brighton, and in those cases the courts are supplied by a tap standing out in the open court. There are very many cases, with quite poor houses, of 5*l*. or 6*l*. of rateable value, which are supplied with taps in the houses also.

Generally speaking, a house of the lower class has a closet of some sort, or a privy; but frequently in the small poor courts there are but one or two closets, common to them all. That which is preferred in Brighton among the poorer classes is Coumin's closet, or rather a pan with a common syphon tap, flushed by hand with a pail.

In 1862 there was a total number of 13,483 services, and at that time there was 722 on the constant, and 12,761 on the intermittent system. The first gradually increased on the constant, and in 1866 there were 2,032 services on the constant system, and 13,091 on the intermittent system.

In 1862 they pumped 1,200,000 gallons per day, including Sundays; and in 1866 they pumped 1,488,000 gallons. The total number of gallons per day for each service or house was,

in 1862, 89 gallons; and in 1866 it was 98 gallons per house. This increase is probably due to a want of supervision, as there is still only one inspector, although the number of houses has considerably increased. The result of investigation shows that the majority of houses rated under 20*l.* a year have been laid on with the constant service.

There have been many new houses of that class built in those five years. It may be considered that the chief of those which have been put on the constant service have been new houses. The new houses have generally the constant service, because the fittings are cheaper. When any one applies to have his house put on the constant system, he is told he must change his service pipe from the intermittent pipe to the constant pipe. That puts a man to a very considerable expense, and consequently there are fewer applications from old houses than from new.

The consumption per house per head, under both systems:—In Washington Street, in which there are 90 houses, at 11*l.* a year rating, they use 16,000 gallons a week on the constant service. The quantity per house was 25·38 gallons; the average number of persons in each house was seven, and the quantity of water consumed was 3·62 gallons per head per day. Those houses have been newly fitted up; they have a ½-inch screwed-down tap over a sink, and they have waterclosets flushed by hand, by pail; that is on the constant service.

There is no cistern to the waterclosets in those houses; they draw the water whenever they like, and as much as they like. Each house has a tap over a sink. The 3·62 gallons include everything, not only the water used, but the water wasted in every shape, from the time it leaves the mains until it gets into the drains, or wherever it goes.

The next instance is on the intermittent system—a street containing 124 houses, from 8*l.* to 10*l.* rating. This was tried for five days on the intermittent service, and five days on the constant service. This is a street which is generally on the intermittent service. They have there chiefly privies, no waterclosets at all; there are about 12 of those, out of the 124 houses, with Coumin's closets attached, and the rest of the houses are flushed by the pail in the way already described. They use 4·64 gallons per head. On the constant system they consumed 6·19 gallons.

Then there is an instance of a better class of houses, rated at from 60*l.* to 100*l.* a year; those were tried for three days. They used 166·66 gallons per house, and 18½ gallons in round numbers per head per day. Those houses have each three waterclosets. There being no power for charging extra, they have as many as they like.

Another row of 52 houses at about 30*l.* rating was tried on the intermittent system. They consumed 21·7 gallons per head; they have one good watercloset fitted up with self-closing valve, and one old-fashioned trapped watercloset, with a common turn-tap, simply a stopcock, which is very wasteful. Another street of small houses, rated at from 4*l.* to 5*l.*, was tried; this was one of the poorest streets in Brighton. The water was laid on last year by order of the corporation, under the Sanitary Act of 1866, and it has been in operation nearly twelve months; the supply was 11¼ gallons per head per diem on the constant service. Thirty of those houses have the water in each case into the house. Twelve of them are fitted with Coumin's closet, and the rest are chiefly flushed by hand. They all have closets, and they all have water, but they draw that water at the tap for other purposes. The remaining twelve houses that have not a tap laid on to each are supplied from one stand-post in the court.

There is a court attached to this little street. "The tap, when I measured it myself, was running at the rate of 180 to 200 gallons per day. It is thought that in Brighton the chief waste of water, whether on the constant or the intermittent service, is amongst the better class of houses."

Mr. Easton, the engineer of the company, considers that every poor house ought to be supplied on the constant system, in the interest of the tenant.

The intermittent system at Brighton is not what the London intermittent system is. They turn the water on at Brighton for four hours daily at each house, and the people are during the remaining twenty hours very badly off for water. No doubt they let the tap run; when it is turned on they never think of turning it off. They take pails out and catch what they can. That no doubt wastes a great deal of water. In such cases it would be to the interest, not only of the consumer, but of the company, with proper regulations, that it should be laid on on the constant system.

Mr. Easton says:—"It is not only my opinion, but the opinion of everybody who knows anything about the poorer class of houses, that a cistern is a great evil, either in London or elsewhere. It is sure to be contaminated. Our inspectors are always going round where you have the constant system. We sometimes have complaints, but very seldom. We generally find that the people do not complain so much of the inspector going to the house in a place like Brighton, but as soon as a fitting is found out of repair, and the gentleman is asked to mend it, then he begins to complain. We had one or two cases last week. One gentleman was very willing that our inspector should go, but

when it turned out that the ball-cock was out of order he was not so pleased that he should have to repair it, and he complained to the Board, and wrote a letter about it. With the poorer class there is no difficulty, because you can walk in and see the tap in every case."

There are four different zones of pressure at Brighton, varying from ten feet above the sea up to 470. The average pressure upon each level, the height rather of the reservoir above the floor of the house, would be about 150 feet in each case. The charge is 9*d.* in the pound on the rateable value for every class of house, poor as well as rich. There are 17 houses at Brighton which are rated at only 1*l.*; they only pay 2¾*d.* per quarter for water. The annual value of the house would be about 30*s.*; the rent cannot be much more.

The town of Manchester was formerly supplied on the intermittent system, but from 1851 to 1853 this system was changed to that of constant supply.

The town was divided into districts over which a careful supervision was established, and every approved appliance was compulsorily introduced. As the districts became accustomed to the new state of things it was gradually put on, until it became a permanent supply upon the constant system. The owners or occupiers may introduce cisterns or not as they please.

The water is supplied under three different pressures, there being three zones of supply according to the varying elevation of the district. The pressure varies generally from 70 to 80 feet up to 150 and 180 feet.

The larger houses are supplied in the ordinary way, either by cisterns or not, because the cistern is not a necessary piece of the apparatus except to the waterclosets. The smaller houses are universally supplied without cisterns, and in the very poor parts of Manchester, where the houses are clustered together, without conveniences for taking the water into the houses, stand pipes, or wall plates as they are called, are introduced, which are the property of the corporation, and to which everybody has access.

The corporation there stands in the place of the water company: everybody is entitled to have water, and everybody is compelled to pay for it whether they have it or not. The corporation lays on the communication pipes to the houses. That is usual with most water companies, and is generally the habit throughout the country.

From the wall of the house into the interior, and all the appliances in the interior, are at the expense of the occupier or owner.

The ordinary cistern pipe is half an inch in diameter, or from three-eighths to half an inch. A large house under the constant supply system requires no more than an inch communication pipe.

The engineer to the waterworks, Mr. Bateman, endeavoured to introduce the custom that the corporation in Manchester should be their own plumbers, as is usual with water companies in general, in order to secure the best materials and workmanship, and the best description of tap or valve. They came, however, to the determination of authorizing a certain number of plumbers who were bound to adopt certain rules and regulations, to introduce pipes of a given strength, with taps and other appliances of approved construction.

With regard to the lower class of houses there is one tap to a cottage house, that is, there is a three-eighth or half-inch pipe, with a tap on it, leading into a house. In many houses in Manchester the pipe is taken down the passage which commonly exists in a lot of cottage houses, and so introduced from the back with a stopcock. A certain number of the houses are commanded by this stopcock where it is taken from the district main, and those houses are dependent upon their water coming through that particular pipe.

In the case of alterations or additions the water has to be shut off, so that a number of houses would during the time the work of alteration lasted have their water supply suspended.* Where the tap is in the house it is over the sink in all cases. They are not common taps, but screw-down taps of the best possible construction. Nothing but supervision can prevent the people from leaving them open, and the water running to waste down the sink.

One kind of tap is a common ground tap; simply a plug with a hole, and the other is a screw tap.

There is scarcely any supervision in Manchester. Mr. Bateman does not consider that, generally speaking, there is any great waste of water in Manchester. The taps are not stolen more than in any other town; they are generally in a room and not in an open place. Nothing but the wall plates are exposed. The taps exposed in the open courts would be liable to freeze and burst, and therefore that is always avoided. Wall taps are secured in the wall against frost or thieves.

A cistern without a waste pipe would be an intolerable thing, because the ballcock might get out of order by accident, and the place might be inundated. In Manchester everybody being entitled to water, there is no stealing.

* On this subject see the Edinburgh supply.

The cost of supplying a cottage house with water all through that part of the kingdom is from 12*s.* to 15*s.* per house for the whole house, including labour and everything. When the system of the intermittent was altered into that of the constant supply, a few pipes may have burst, but there was no systematic change in the pipes, although the pressure was increased some 70 or 80 feet all over the district. Half-inch pipes are in general use in the north of England, about six pounds to the yard.

At Newcastle-on-Tyne the water has always been delivered on the constant supply system, but the consumption gradually increasing to an extravagant extent a vigilant inspection was introduced, and proper means were taken for checking the wasteful expenditure of water. The manager of the company considered that 23 gallons per head per diem, for domestic purposes only, was an excessive quantity, and he determined to ascertain where the water went to. He therefore had the town divided into small districts of three or four streets, completely isolated, and put in a street meter to register the daily consumption.

On comparing the districts where watercloseta prevailed, with those in which there were none or only a few, it was found that the watercloset was the great consumer, generally from their being out of order, and very often from the crank handle being propped up. Where this occurred amongst the better class of houses the consumption was at the rate of 55 and even 80 gallons per head per day. In this case the number of watercloseta would average one to every six persons.

The other houses were smaller, and there were fewer watercloseta; one to thirty-five inhabitants in one case, and one to forty-eight inhabitants in two other cases, and one to 157 inhabitants in another case. The consumption of water varied from 11 gallons per head per day where the watercloseta were the least numerous, to 30 gallons per head per day where they were most common.

In order to put a stop to so flagrant a waste of water, they put a staff of men to examine every watercloset and tap, and to report thereon, leaving a notice that if things were not put in order within three days the supply would be stopped.

After the lapse of three days another set of men followed, inspecting those places reported as leaking, and shutting off the water where the notice had been disregarded. In this way an immense waste was stopped, the effect being immediately apparent in increased pressure throughout the town. But that measure only answered as a temporary purpose, and could not be relied

upon to effect any permanent saving. For upwards of twelve months they have been going on systematically replacing the present waterclosets with Guest and Chrimes' double-valve cistern, and Thomson and Murray's valve cistern, neither of which can be propped to cause a continuous run. In this case one district has been reduced from 55 to 34 gallons per head per day; another from 60 to 35 gallons; another from 61 to 25 gallons, and again in another from 62 to 26 gallons per head per day.

In carrying out the change there was some opposition, but not to any extent. In one district new double-valve cisterns were put into every house by arrangement with the landlords. The result was as follows: that from 32½ gallons per head per day the consumption was reduced to 16½ gallons per head per day; in another case the consumption per day before the improvement in the waterclosets and taps was 31 gallons per head; and after the improvement it was 12 gallons per head. The general result of the investigation as to waste was, that where everything was in good order there is no disadvantage to either party by the supply of water on the constant supply system, while the advantage to the consumer is comparatively greater than can be enjoyed under the intermittent system. If the regulations are observed as to waste, the constant system will consume no more water than the intermittent. Those who prefer to abandon their cisterns and take their water direct from the pipes can do so at very little expense. Complaints of inconvenience arising from interruption to the supply of water are not very often heard in towns where the supply is at work.

In the Newcastle and Gateshead Waterworks Act of 1863 there are important clauses having reference to the considerable powers which are vested in the company for the purpose of introducing the best kind of water, and giving them the power of cutting it off in cases where the regulations are not complied with.

In Edinburgh, before the year 1852, the supply was on the intermittent system, after which the company changed to the constant supply. In making that change in 1852, some 10,000*l.* or 12,000*l.* were expended in enlarging the mains, and in other expenses.

The supply at Edinburgh is entirely by gravitation; the water is not raised mechanically at all. That had been the case from the commencement of the company in the year 1819. With a few occasional and unavoidable exceptions, arising from excessive droughts, they have been supplying upon the constant system ever since 1852.

In the year 1864 the drought was excessive in Scotland, and

the consequence was that the reservoirs in the hills got almost all emptied, and the company was obliged to reduce the delivery. They distributed the supply in the best way possible, but it was not a constant supply. Since the change has taken place in Edinburgh the system has been very much more approved than it was before; it has been altogether better. No one can have any experience of the two systems, as says the engineer of the company, without being able to appreciate the advantages of the constant system.

There are difficulties to overcome with reference to the prevention of waste; and for the proper exercise of the constant system it may fairly be considered that the company should have stringent powers as regards the appliances in the houses. The Edinburgh Company find that with a proper control over the house fittings, and a proper supervision in every way, a constant supply of water can be better given with a small quantity than can be done on the intermittent system.

The whole power which the company had, when they first changed their supply, to insist upon improved fittings being put on, was the power granted under the "Waterworks Clauses Act." After this general Act was incorporated with the Company's Act, the company instituted more strict supervision to prevent waste, or they could not have maintained the system of constant service. They were obliged to keep up a very strict inspection to prevent the waste from the waterclosets. The people in Edinburgh, as in most large towns, have the habit of allowing the water to run to waste by means of the watercloset for days and days, and the waste there was quite enormous.

They have established a staff of officers whose business it is to make inspection and prevent waste arising from that or any other source. The company obtained additional powers in 1863, and they have introduced a better system of cocks and taps, but there was great difficulty in getting them adopted. The plumbers in Edinburgh, as everywhere else, resist every kind of improvement in water apparatus. The company's engineer tried for a number of years to introduce the new system of tap, the screw tap, a loose valve screwed down. It is as cheap as the old kind of tap; the only repair it can ever want is the replacing of the leather washers, which is a very inexpensive thing. But the plumbers are so very adverse to their adoption that very often in putting them on, instead of putting the tap down they keep it screwed up, and in attaching this by hot solder to the tap the leathers get scorched, and that ruins the tap. This is one of the difficulties there is to contend against; but in order to show what the waste of water from a very small source may be, the engineer had discs constructed a few years

ago. One, the size of which was 0·05 inch, with 150 feet of pressure, discharged in twenty-four hours 1613 gallons; then another disc was one-tenth of an inch; that discharged, with the same pressure, and in the same time, 2380 gallons. With regard to the others, that pressure could not be maintained in these experiments; it was 120 feet on four-tenths of an inch, and through that there passed 34,280 gallons. This will give some idea of the loss of water from having a tap open for a very short time.

At present the consumption in Edinburgh is 35 gallons per head per day; that is a very large consumption. The service is constantly on, night and day. That 35 gallons per head includes the supply for every purpose.

They have arrived very nearly to the purposes other than those for domestic use, and it amounts very nearly to 14 per cent. If the company had the power of taking proper means to prevent waste, the consumption, with a supply equally full, and probably more satisfactory, would be reduced to something like 18 gallons per head; not over 20 at all events. The power required for that purpose would be that of prescribing the description of apparatus and taps to be used. Care would be taken that no water was supplied when the taps were not of the proper description.

A person could not leave this new tap open and the water running so readily as with the other, because it requires two or three turns to open it fully; it has besides another important advantage over the old system of tap, that is, in order to shut the water off, that it requires a half turn only to open it out, and the shutting of it suddenly produces a shock in the interior of the body of the pipe; that shock disturbs the lead, the pipe will at some time give way, and there is a flood.

In this new tap, on the contrary, there is not the slightest shock; it is screwed down so gently or gradually that there is not the least shock upon the pipe from regurgitation. Care is taken that the house is inspected constantly to see that it is supplied with the proper apparatus and taps. If it was found that there were continued derangements, notice would be given to the occupier to set it right, and if not attended to, the water should be cut off.

There would be a difference in practice between the pressure on the pipe in the intermittent system and the pressure upon that pipe under the constant supply. When the water is turned on at the main, the shock of the water suddenly turned on on the intermittent system, in rushing with great force into the interior of the pipes, strains them. That is avoided by a constant steady pressure; that distinction about the strain is still further

increased by the old tap; both defects are got rid of by the new tap.

There has been no alteration required to be made in Edinburgh to repair a house pipe for the constant service. At the time the change of supplies took place, the fittings which had been used for the intermittent system went on without change for the constant service, and for a long time the company supplied in that way, and they are still the same in a great many cases.

In introducing water for the first time into a house, it can be introduced at less cost on the principle of constant service, putting in proper apparatus; and the expense of maintaining that apparatus is very much less than the cost of maintaining on the ordinary intermittent system. In the case of a house already supplied with the intermittent service, it would be difficult to give a correct idea of cost of putting the proper apparatus for constant service. In Edinburgh there is a vast extent of apparatus, perhaps more than in any other town of the same character.

The number of waterclosets is enormous; there are baths in houses of even very low rents, and the expense of alteration from one system to another would depend upon the present condition of the house fittings, and the character of the apparatus in use. In the case of waterclosets a cistern is indispensable. In regard to the older houses, the apparatus is generally very badly constructed, and the cisterns and the apparatus connected with them for the waterclosets are generally rather small.

The water is run off with great force and very suddenly, and a very small quantity of water in that case is sufficient at a time; but when a cistern is erected in a house for common domestic purposes, and the water is let down into the watercloset by a small pipe, they very often keep it always running; it does no good, although there is a prevalent and ill-considered opinion that it cleanses the drains; the only effect really produced is to fill the house with bad air.

A house can be supplied with a small watercloset, and a small cistern for the watercloset, and a single tap placed in a convenient situation, for about 2*l.* or 2*l.* 10*s.*; it depends more or less upon the distance from the main. The cistern would be of iron, to hold about 5 or 6 gallons of water, that being supplied on the usual system, with double valves, so that in letting out the water from the cistern, no more can be had until the handle is released, and it fills again.

It is found in Edinburgh that where a pipe on the intermittent system, with the old tap, is strong enough, then it is strong

enough with the new tap on the constant supply. The pressure varies from 450 feet down to 4 or 5 feet.

The weight of the pipes prescribed since the passing of the Act of 1863 is 6½ lbs. per yard for the half-inch pipe, and 9 lbs. for the three-quarter-inch pipes.

The pressure is great enough to work the pipes as fire-engines without machinery. When the fire-cock is put on a small main, it is generally contrived to turn on an additional supply of water to it with greater force; more pressure is had by that means. There is no pumping; it is all gravitation. This applies to all parts of the town and even the suburbs. Leith and Portobello are all supplied by gravitation; there is no pumping power of any kind. The company delivers at a height of about 450 feet above high-water mark.

A well-laid main should hardly ever require repair. If any alteration is required, such as soldering a new pipe into a main for a common extension or service pipe, it is not necessary to turn the water off; there is an apparatus to obviate this. Upon the end of a ferrule is a cock, that is inserted, first drilling the main; when the iron is almost through, the screw of the ferrule is applied to it, and screwed in; the cock is shut all the time it is kept shut. This is a recent and very useful invention.

Whenever there are repairs wanted upon a district main, all the houses upon that district main would be deprived of water.

The source of supply of Edinburgh is from the Pentland Hills, and the company is now bringing in about 800 cubic feet per minute; of that there is about 470 feet from pure springs, and which never sees the light until drawn by the consumer. That is from an elevation which will supply the water to every variation of the level in Edinburgh itself. There are no less than eight reservoirs at different levels on the hills.

There is only one distributing reservoir in Edinburgh proper; that is on Castle Hill; it is 350 feet above the tide level. As regards the principal reservoirs, the supply being entirely by gravitation, it is from reservoirs made in the hills at some distance from the city; they are all at different distances, the furthest one being about 14 miles, but that is a compensation reservoir for the spring water which is taken away from the drainage area; but the springs are all collected and carried past that in an aqueduct, to compensate the mill-owners.

This compensation reservoir is not at all available for the supply for the city, but some of the others are. The nearest that is actually used for the supply of the city is about five miles off, and the most distant about nine miles.

In Cambridge the supply is from the Cambridge University and Town Waterworks. The supply is, and always has been, under the constant supply system. The average pressure is about 120 feet. The consumption at first was very great indeed; in the first half of the year 1865 the gross consumption per head per day was 31 gallons, including the whole supply, domestic and trade. This was a fair average of the consumption before measures were taken which resulted in reducing that consumption.

The trade consumption amounts to 8·87 gallons per head per day, which would leave 22·13 gallons for domestic consumption. In the year 1865 the company began to take measures to inspect the defective fittings, and to ensure a better set of fittings in the town. It was found that if the consumption went on at the same rate at which it was going on then, the company would have had to increase their engine power and the capacity of the mains. After those measures had been taken, the gross consumption in the first half of the year 1866 was 19·1 gallons, as opposed to 31 gallons in 1865.

The trade consumption was less in the first half of the year 1866 than it was in the corresponding half of the year 1865. It was 7·83 gallons, as contrasted with 8·87 gallons in 1865. That left for domestic use 11·27 gallons per head per day. In this statement of 11·27 gallons, the full capacity of the pumps is taken.

To ascertain the actual quantity of water taken in the town, we ought to allow a certain percentage, perhaps 10 per cent., for leakages in the pumps. That would reduce the consumption for domestic purposes to 10·15 gallons per head per day; domestic purposes include the supply to houses generally, for waterclosets, baths, and so on, and all general trades, such as grocers, drapers, and druggists; those are what are called day trades; brewers are not included in this.

In connexion with the domestic supply, the Cambridge Company allow water to be used, free of charge, for watering the gardens and lawns attached to the houses; this is included in domestic purposes. It may be observed that in this town there are several houses where there are taps in the gardens, and the water is supplied by the force of pressure to a great distance.

There is one instance where a gentleman has seven taps in his garden for watering lawns.

The breweries are supplied by meter, and that is included in the trade consumption.

The reduction in the consumption is due almost entirely to the repair of defective fittings. With reference to the waste occasioned by the ball-cock watercloset cistern, it may be observed that upon examination of the ball-tap of a watercloset cistern, it

was found to be out of order; it wasted the water down the waste pipe at the rate of 10,000 gallons per day. The waste pipe was improperly connected; it was connected with the drain, so that the waste could not be perceived.

It may be remarked here that it is the practice of plumbers, in order to let the water run to waste in the cisterns, to introduce what they call "deafeners," which are rags attached to the waste pipe to prevent people hearing that the water is running to waste.

As soon as the waste in the above-mentioned instance was discovered, steps were taken to remedy the evil. The only thing that was needed was to change the ball-cock to stop the waste; and as the waste pipe was improperly connected with the drain, it was also necessary to alter the waste pipe in accordance with the company's rules.

The cost of that to the company would be 6*s.*; 10*s.* was charged, showing a profit to the company of 4*s.* Supposing a new ball-cock only to have been needed to prevent the waste, it would have involved a cost of 4*s.*; there would have been a charge of 8*s.*, and a profit to the company of 4*s.*

In many cases the waste of water has been stopped by putting an indiarubber valve on to the ball-cock at the cost of 1s. In frequent cases the waste of water was stopped at the charge of 1*s.*

The investigation of these cases of course involves a good deal of visiting and inspection. The company's officers did not experience the least difficulty, nor was any dissatisfaction expressed on the part of the water consumers. The necessary charges for the alterations were paid willingly and without any complaints. The accounts were all soon paid.

The change took place before 1866; from that time until the present summer of 1867 there has been no further inspection, and the consumption is now slightly less than it was.

The company execute fitting-work, but it is left open to the town plumbers. In the case of all the taps they put on, those are kept in repair; the washers or valves without charge. There have been no cases in which repairs to either cock or tap have been required since the company has taken charge. The cost to the company has been nothing for four years. The weight of the half-inch pipe is 5 lbs. to the yard, and it is seldom any other is used. The company make the provision of fittings a source of profit to themselves; they make a profit of about 35 per cent. upon the total amounts of the fitting accounts.

There are only one or two cases in Cambridge where cisterns are used for domestic supply; that is where there have been new

houses built, and the architect has been a London architect; cisterns are not recommended, neither are they prohibited. The company, however, discountenances them, because the water drawn fresh from the mains is superior and better for domestic purposes, more particularly for drinking, than it could possibly be from a cistern.

Cisterns in connexion with waterclosets have been examined, and found to contain great impurities. The great majority of cisterns are watercloset cisterns, with the ordinary apparatus.

It is a regulation that the overflow, instead of being carried into a drain, shall be turned in some position where an escape of water may be noticed. Stop-cocks are not allowed without special permission. The stop-cock is placed generally just inside the house on the communication pipe from the main. If they were put in another place the water might be used for a different purpose; they are not frequently used for small houses.

In attaching the services full-bore ferrules are used; that is, just half-an-inch diameter, and that supplies a pipe of just the same diameter. There is no restriction whatever in that respect. When the company was first established they did use a few small-bore ferrules, but they were found not to answer.

It has not been found necessary to place any restriction upon the number or position of the taps used for domestic purposes. It is simply a matter of convenience to the consumers, and they go to whatever expense they please in the matter. There is no alteration in the charge in any way with regard to any variation in the height of supply required. The company can supply to the top of the highest house in the town, and it makes no difference in the charge. Separate service pipes are not required for each house.

In the case of a large new house in Cambridge the cost of introducing the water fittings (including the ball-cocks to the cisterns), would be, with three waterclosets, about 7*l.* or 8*l.* The cost in the case of a small house, not above 10*l.* per year, would be about 10*s.* or 15*s.* Sometimes, however, a tap supplies a number of houses, and there have been instances of the cost not exceeding 1*s.* 6*d.*

The cost of 10*s.* or 15*s.* includes an allowance for 20 feet of communication pipe and a tap; there would be no cisterns to small houses.

Cambridge is very well supplied naturally with water. By pumps the water can be got within a few feet of the surface by boring, and there is Hobson's stream running down two streets of the town, and a few inhabitants get their water from it, but the company's water is taken for convenience in many cases. The

Cambridge waterworks get their supply from a spring at Cherry Hinton, three miles from Cambridge.

Intermittent Supply.

We will now give the arguments which are brought forward in support of the intermittent supply. From the information of the experienced hydraulic engineer, Mr. J. Simpson, we gather the following notes.

In Bristol the constant supply is without cisterns, with the exception of the waterclosets, but there were old waterworks which the company took to, and the inhabitants in many parts of Bristol have retained their cisterns.

The great source of waste there is the abuse of the waterclosets; they prop up the valves with the idea of flushing the waste pipes. There is now an improved system of watercloset, which prevents any abuse of that sort; it was the invention of the resident engineer at Bristol. The company are recommending the application of it in all cases; if this recommendation is complied with, it gets rid to a great extent of that source of waste.

The water at Bristol comes from a series of springs, taken up at Chewton Mendip, about four miles from Wells, going south of the city. It skirts the Mendip hills, taking up other streams at Harptree and terminating at Dundry, where there is a large reservoir. The supply is limited; it is a very bad country for water.

The cost of the apparatus which would prevent the waste of water in the waterclosets, which has been mentioned, is about 16*s.* for each watercloset. "I do not know," observes Mr. Simpson, "whether it would satisfy everybody, because practically it limits the quantity to about a gallon, and many persons think that is not enough to flush a closet. It is necessary to wait until it fills again."

The inhabitants in Bristol are in the habit of extending the pipes to the sinks, where they have been left away from them, and they are not at all particular about using the water. In the district of Clifton, the better part of Bristol, the quantity of water running at night measured from a reservoir, was found to exceed the daily supply. The resident engineer paid particular attention to the subject, and discovered that many of the inhabitants hooked up the waterclosets, and that the water ran constantly, so that it increased the supply very much; so much so, that at certain seasons there has not been water enough for the necessary supply.

The company has now been taking water from another district,

and by means of more vigilant inspection, and the consequent prevention of waste, to the detriment of a large number of the inhabitants. It is a somewhat difficult problem to solve practically and satisfactorily.

There is in fact a point of contention between the company's inspectors and the inhabitants; the company furnishes the pipes away from the sinks, and the people draw the water and take it to the sinks; very often the plumbers are called in, and make the connexion between the two.

The Carlisle Waterworks were established some seventeen or eighteen years ago, on the constant system, which has been continued ever since. Carlisle is in a very unpleasant state about the water; the waste has gone on so long and become so uncontrollable, that they do not know what to do with it. Last year (1866) the Board of Health, the Town Council, purchased the works, and are now about making arrangements to endeavour to overcome the difficulty. In all probability they will continue to adhere to the constant supply system, but it will be controlled to some extent; it cannot go on as it has done. If they had all the water in the river Eden the present rate of consumption or waste could not be satisfied.

The pipes are laid in and terminated in most instances over the sinks. That, however, is not the only source of waste; there are certain taps in the streets, the markets, and places where passers-by, boys and mischievous people, turn on the water and leave it running, and a great deal of waste proceeds from that source. Altogether the system requires much greater attention, and to be followed out with much greater strictness, than it has ever been in Carlisle. The fact is the company was established without an Act of Parliament, and they have felt the difficulty.

Mr. Simpson constructed the works at Carlisle, and they actually started those works and supplied water for all purposes to the extent of only 12 gallons per head per day, and this went on for some time, but the inhabitants got into the habit of using the water, it being more easy of access than it had been, and there was a well-founded impression in the town that the water from the old red sandstone was very bad, whereas the water from the Eden was very fine. The last time the water was measured in Carlisle it was 28 gallons per head per day, and the waste has got so much beyond the power of the works that they are now bringing a duplicate engine to bear, and are going to lay another main.

The constant supply system at Croydon has been said to be a failure. There is no power to control the supply, and the inhabitants are in the habit of using gutta percha pipes, and the lawns

may be seen three inches deep in water, when the inhabitants in places a little above the common level could not get water at all.

The water in this case is carried in without cisterns, and in some cases over sinks and in some cases not; they have a rather vigilant inspector there, but yet the town is very badly supplied. There is a simple delivery pipe into the house with a cock, without a sink in a majority of cases. But they have lately been advocating cisterns in Croydon, as they have often found it very inconvenient to be left without water when it has been turned off. The inhabitants have been recommended to put in cisterns, although previously they had only watercloset systems. They get their water from wells sunk in the chalk: it is in connexion with the river Bourne, an underground stream, which occasionally flows to the surface.

The water at Croydon is said to be shut off every night, and is frequently kept off many hours.

A great deal has been said with reference to Croydon about pipes bursting, and consequent deficiency of supply. It would, however, be rather difficult to connect these circumstances with the advantages or disadvantages of the constant supply, or with the source from which the water is derived. Mr. Simpson, however, states, and of course perfectly correctly, that on one occasion when a "great number of pipes burst," the inhabitants of Croydon were so badly off for water that when the Lambeth Waterworks put up their stand-pipes additional men were employed to carry water wherever the inhabitants required it, without distinction. This supply to the Croydon people was considerable, and just after a frost. "If that was to be the effect of the test of frost on the constant supply, it certainly was a lamentable one, for the number of bursts was immense. Under the constant supply, if a pipe bursts you must cut off the whole supply to mend the pipe, unless stopcocks are put on, which are objected to under that system, because it is said to offer an opportunity for persons tampering with the pipes."

The constant supply at Croydon, which is carried on under a local board of health, has been found an impracticability as regards raising any sufficient quantity of water. There is this difficulty, that the people use so much water in the lower part of the town, and do it so unwarrantably, that the upper parts are deprived of it altogether.

The INTERMITTENT SYSTEM "has its faults and inconveniences, but the sanitary object must not be lost sight of. Introducing a large quantity of water within one or two hours of the day flushes the drains, and that must be very beneficial in dry weather."

One of the difficulties, or one of the things which is said to make stronger pipes necessary for constant supply, is the concussion which is caused by shutting every tap when there is pressure on. When a tap is suddenly turned there is a kind of blow given, which arises from the regurgitation of the water. To some extent, we have counteracted the effects of that blow in the constant supply by putting a small ferrule on, a practice which, by-the-bye, is also introduced on the intermittent, and the result is to attenuate the water, and by the use of screw-taps there is a sufficient interval to "destroy the regurgitation."

The discharge by this means may be contracted to what may comparatively be called a mere dribble, and in many cases this would be very inconvenient.

Mr. Simpson thinks that if an unlimited supply of water can be obtained it is a good thing that the public should have the benefit of that supply. We have, of course, to regulate our supply according to our means. It may, therefore, be very possible in a small town with a moderate population to give a constant supply, and practically an impossibility when you have three million inhabitants to deal with, and that is the problem which has to be solved for London.

It must be borne in mind that in large towns, where there is great wealth, luxury is not only studied, but is carried to the extreme of indulgence. If we were to change in London to the constant system of supply there must be compulsory legislation for the alteration of fittings, and this would not affect the companies only, but the whole of the public. So far as Mr. Simpson's information enables him to judge, he considers that the general average of the cost of altering the fittings throughout the whole of London may be estimated at about 5*l.* in the lower class of houses; in the middle class at about 10*l.*; and in the large class at 15*l.* Taking that over the whole of London, it would amount to about 2,500,000*l.* or 3,000,000*l.* That would fall upon the present landlords of the houses, and this, he considers, they would resist.

He also considers that in all large towns, such as London, where the intermittent system has been adopted and in use for a great number of years, there would be a great objection on the part of house occupiers to the system of inspection required under the constant supply system. There is no doubt that stringent legal enactments would be required before it could be carried out as regards the better kind of houses.

He does not consider that water drawn by the consumer directly from the water company's pipes, under the constant system, would be any cooler than that drawn from the cisterns under the inter-

mittent supply. Neither does he think that the water stored in cisterns under the intermittent supply is liable to any contamination, and he believes that it is kept there as pure as in the company's mains.

With regard to the injury from storing in cisterns, he considers that this is very much exaggerated, and that parties who keep their cisterns in proper order do not find it, and also that practically the water supplied through the cistern is generally as good in quality as when it comes into the cistern, and when they are covered there is nothing to contaminate the water.

Against all this, however, it may be urged that if there were nothing to contaminate the water after its reception in the cistern, then the cistern cannot require cleaning out; but we know that these receptacles of the London water do require cleansing, even when they are otherwise properly cared for.

It is by no means common in such places as London, to meet with people who know how to take care of their cisterns, or who have any practical knowledge as to the care required to keep waters that are stored in a good condition. Quite lately we have found that in the North of London, and amongst very respectable people, it was a practice to keep fish in the cisterns, with the notion that they devoured insects, and kept the water clean. We know besides that it is very usual to leave the care of the cisterns to servants, who know very little about the matter, and care less.

Amongst the poorer classes of houses the system of storage as practically carried out at the present time is simply an abomination. Even the advocates of the intermittent system admit that an immense number of the working and the poorer people are obliged to store their water insufficiently and improperly; they have no means of doing better, and they do not know better.

If there is any truth in the opinion that organic matter in drinking-water is unwholesome, it is equally true that at present the classes referred to require on this point almost as much care as children. It rests a great deal on our profession to set these matters right.

From the observations of the engineer to the New River Company, it may very plainly be gathered that it is not only the constant supply system that requires inspection and "*stricter supervision.*"

The New River Company have the means of making storage reservoirs giving roughly 10 million gallons per day in addition to the 21½ million gallons now taken direct from the stream. By this means they could collect all the flood water now running to waste.

The following is the account of the quantities of water delivered in the New River district for some years past:—

Year.	Average number of gallons supplied.
1856	20,396,400
1857*	25,087,769
1858	24,992,334
1859	24,988,151
1860	20,801,278
1861	22,837,000
1862	23,260,341
1863	23,834,673
1864	24,718,452
1865	23,496,866
1866	22,898,769

It will be seen that in the year 1866 the quantity was almost precisely the same as in the year 1861. In 1856 the number of houses was 96,661, and in 1866 it was 112,964.

The company's dividend in 1861 was 4*l.* 1*s.* 1*d.* per cent., and in the year 1866 it was 6*l.* 2*s.* 2½*d.* per cent. In 1866 they appropriated a further sum out of a reserved fund amongst the shareholders; they gave 1400*l.*, or 6*l.* 11*s.* 6¾*d.* per cent. Although the number of houses in the district had increased, as well as the area of the district, and pipes had been laid further into the district as the houses had been built, the quantity of water delivered had been considerably diminished, *chiefly from a stricter supervision of the apparatus to the tenants' houses securing greater care against waste.*

It would not be undeserving of enquiry to ascertain why the people should object to supervision in their houses under the constant system any more than for an intermittent supply.

"The diminution has been caused by the *use of superior fittings*, which has prevented waste;" under this condition it may certainly be argued that the waste so much complained of by the companies does not arise only from wilfulness or carelessness on the part of the people, but also from the company's not securing powers to see that proper fittings are introduced in the houses.

There was no restriction whatever in the quantity of water the tenants could have for actual use, except of course turning it off when the company considered there had been enough delivered.

The supply was turned on in every case so as to fill all the

* The sudden increase in 1857 was caused by a sudden rise in the number of houses, the Hampstead Waterworks district then being incorporated with that of the New River.

cisterns provided by the consumers for their use. It was simply by preventing water from running to waste in drains and otherwise that this economy in water was effected. The number of days during which the supply was given was rather greater; but it does not follow necessarily that the time during which the water was turned on was the same as before. No information could be obtained from the company as to the length of time, during each day, for which the water was turned on.

It was merely stated that the length of time varied with the circumstances of the street, and possibly it might be added with the quantity of water the company had to spare.

The general rule was to turn on the water long enough to fill all the cisterns in the houses in any particular street, and if by stopping waste the time could be made shorter, it was made shorter. There is a practical lesson contained in those few words, and the argument may be used in two different manners. With a three-quarter-inch or inch pipe the cisterns in the houses of any street would soon be filled; that being done, the water might be turned off; but in such cases what can be the supply to that numerous class of the population which is dependent on catching water in the best manner they can, and storing it anywhere? It is useless to talk of education to people who have not water to wash with. This is one of the questions in relation to waterworks and water-supply with which our profession must shortly deal.

In the East, where water is generally far more valuable than in English towns, we have seen the water running all day from public fountains to which all had access, but the delivery pipes are barely of the size of a quill, so that if the water is left running to waste for a short time that waste is not very considerable; and yet many of these people we are in the habit of looking on as only half civilized.

The engineer to the New River Company considers that some seven gallons per head per day is the quantity actually required for domestic purposes. He made an experiment some years ago on rather a large scale in some model lodging-houses where there was an abundant cisternage supplied, and where the people had every means of using water, with waste prevented, and he found the consumption to be seven gallons, as above stated.

On the subject of supplying any portion of London on the constant system with the present fittings, this engineer supplies us with the following information:—"I can give an instance from actual experiments lately made to prove that with the fittings as they are now, the consumption would be so much increased that the proper supply of the inhabitants would be quite impossible. Lately the New River Company placed upon

one of their district mains a meter, and tried what the consumption of water was under the existing intermittent system. It was then found to be something like seven or eight gallons per head, and after a month's trial in this way a supply was left on, so as to be what is called constant. The result was that sixteen times the quantity of water was taken under the constant system that had been taken under the ordinary intermittent system.* There is no doubt that the increased supply went to waste, and was not consumed for the domestic purposes of the persons to whom it was supplied; so that under a system of constant supply, there would necessarily be a much larger amount of waste than under the present system, unless the existing fittings were altered to the constant supply."

He also considers that the present fittings would not be at all capable of sustaining the constant supply pressure, because in the case above referred to, of 121 houses on which the experiments were made, 18 of the lead pipes were burst by the additional pressure that took place at certain hours of the day, and various leakages occurred. A very extensive supervision would be needful to keep things in order under a system of constant supply. He estimates that no less a sum than 8*l.* per house as an average would be necessary to make the alterations, and that these over the whole of London would cost more than 3,000,000*l.*

We also learn that the company have another means of limiting the supply passing through the supply pipe; this is what is called a "ferrule." It is merely a reduced orifice by which some limit is put to the extravagant waste which might take place if the pipe had the full bore throughout; it is in fact a narrowing of the pipe at its connexion with the company's main.

The engineer to the East London Waterworks has supplied a considerable amount of information which will be practically valuable to the engineers who have not had actual practice as regards water supplies.

The East London Waterworks Company has given a continuous supply, using the term "continuous" in distinction from that known as the constant supply. Up to the end of the year 1866, the company's district contained about 92,000 houses, and to 25,000 of these this continuous supply was afforded. This is done by means of the "ferrule" inserted in the service pipe communicating with the house. This limits the quantity of water supplied, and consequently the amount of waste.

* The consumption must have been at the rate of about 120 gallons per head, or about double the maximum quantity which Loch Katrine supplies to the inhabitants of Glasgow.

"In giving the supply to the 25,000 houses, a piece of metal, with a small orifice in it, is inserted in the pipe, which orifice governs the amount discharged into the lead pipe. It can be precisely regulated according to the size of the house, or to the consumption, so as to give a larger or less supply. With any known pressure, or any given known circumstances, that orifice may be arranged so that the house may receive any quantity. We put no restrictions on the size of the cisterns; it is rather an advisable thing that the public should have cisterns of sufficient size, and that they should not have any influence put upon them to diminish the cisterns at all. We do not recognise any supply without a cistern; and this system is not intended to do away with cisterns at all, but rather to be made to work jointly with the use of cisterns. A cistern would be necessary with the use of the small pipe. From my knowledge of the east of London, it appears to me that this is the best mode of giving anything in the nature of a constant supply to a district of that kind. It seems to me to be the most feasible and beneficial, and the best means of preventing waste among the class of houses and people that we have to deal with. There are 90,000 houses in round numbers in our district. As many as 60,000 of those are of a value under 20*l.* a year; and 20,000 more I believe, are under 30*l.* a year. This is not what is commonly called the constant supply. It would be madness to attempt to supply our end of London on a system of constant supply; that is, unlimited control over the water, with a pipe of, say, half an inch diameter. The constant supply means good fittings. It means a half-inch lead pipe—that is to say, a pipe with a half-inch interior bore—a cistern, and a ball-cock and apparatus, which must be of good character. In hundreds of thousands (?) of houses in our end of London those things would be stolen directly, and they would be out of order continually in a great many more; therefore they would require not only supervision on our part to prevent waste, but supervision on the part of the landlord to preserve his fittings. Any injury that would take place to the fittings, either by the abstraction of lead or brass taps, would lead to an indefinite amount of waste to the company. It not only would do so, but it does do so under present circumstances. Theft of all the fittings is continually going on, and people come to us holding up their hands, and begging us to have mercy upon them, and to relax our stringency in compelling them to have brass taps and ball-cocks on once or twice a year, which we have to do continually. We have a set of men whose special duty it is to examine the condition and report, and enforce the improvement of those fittings throughout. They go systematically through the whole district,

and go as often as we will, we do not find less than one house in four requiring repairs and improvements. I think that something in the nature of a constant supply of the sort such as we give now, would be the best sort of thing that could be given to the poor under existing circumstances, and under the present state of the law, and seeing the difficulty there is in getting landlords to fit up houses properly. The difficulty which exists in getting landlords to supply houses with adequate cisternage in some sense condescends to their bad ways, and this would give the public, and the poor particularly, a better supply of water than they would have with imperfect cisterns under the intermittent system. The storage is very deficient through a great part of East London; 20 per cent. of the houses of the whole district have not anything better than an 18-gallon tub, and out of that 20 per cent. many would have none at all. A great deal of water is continually stored in bedrooms and within the house in most objectionable and offensive ways."

It is a very grave mistake to neglect cleaning out cisterns; this should be done periodically, or they become foul. Even in the houses of the rich they become so; and yet there are hundreds of houses where the covers of the cisterns are never lifted for years together. In well-conditioned houses on the intermittent supply every cistern should be supplied with an apparatus of a simple description for the purposes of cleansing.

On the subject of making alterations in London from the intermittent system to that which is distinctly recognised as the constant supply, the engineer to the East London Waterworks considers that as regards that particular district, and assuming that in houses of the class they supply there was a tap and a constant supply to that tap, the cost could not well amount to more than 2*l.* a house. "I doubt whether it would amount to so much as that. I do not think it would be wise to put it as low as 1*l.*, because we should use the opportunity for enforcing a better condition of cisterns and better apparatus all through; there is very little doubt that in the majority of our districts the waterclosets use two-thirds of the domestic supply of water. I daresay it might be done for 1*l.* if the watercloset question were separated from it."

On every system the whole set of pipes may be divided into three—the mains, the services, and the communication-pipes. The mains are always charged; the service-pipes will be always charged on the constant system, but only intermittently charged for certain hours and minutes in the day on the intermittent system; communication-pipes will follow service-pipes, and be constantly charged with the service-pipes on the constant system.

The service-pipe runs parallel with the houses, and parallel probably to the main pipe, if there is one; but in a branch street without a main, the service-pipe would be at right angles to the main in the next street. It is to the service-pipes that the communication-pipes are attached, and one cock stands between the service-pipe and the main.

The constant service has an able advocate in Mr. Bateman, besides public opinion which of late years has gradually rallied to this subject. His opinions and statements are in very many respects diametrically opposed to those we have given above as regards the intermittent supply.

He considers, of course, that a new tap must be introduced in all cases before the constant supply can be adopted. The cost would be only from 1*s.* 9*d.* to 2*s.* 6*d.* If the old pipes could be conveniently removed, those pipes being larger now, and, therefore, heavier per yard than those which would be needed under the constant supply system, most likely the money obtained for the old pipe would pay the whole cost of the new, and in some cases more than that. I consider the evidence as to the cost averaging 8*l.* or 10*l.*, or even 12*l.* a house, a very exaggerated estimate.

He does not concur in the opinion that it would be necessary to entirely refit a house with new pipes, taps, and everything else, and that they would cost 8*l.* The mere introduction of a pipe without a watercloset in the poorer houses would not be more than 15*s.*; call it 1*l.*, and the watercloset additional need not be more than another 1*l.*, so that 2*l.* would be sufficient for a vast number of houses, with a new supply entirely, and a watercloset. Very considerable power ought to be given to somebody in the passing of a bill for the purpose of seeing that the pipes, and everything that is used, is of the best construction, that the work is properly done, and also for preventing waste.

Mr. Bateman considers that the "plug" system in London is a disgrace to our profession, and to the mechanical ingenuity of the age that it should be allowed to exist. He suggests the introduction of the improved fire-cocks, of which about 120,000 have been employed, on a pattern which was first introduced in Manchester, by which immediate communication is had with the pipe, and which costs probably, after the whole expense is included, about 30*s.* a cock. It is only suitable for the constant supply. He concurs with Captain Shaw in thinking that constant supply is necessary. In almost all the cases where he is engineer, the fire engine has been discontinued. The water is obtained from the main-pipes almost instantaneously, and the fire-engines are merely used as omnibuses to carry the men and their apparatus. He saw no difficulty in introducing a system like that in London, and could

not understand the estimates which have been sent in, and laid before this committee. "I see it has been estimated that it would cost 10*l.* per hydrant, and that 150,000*l.* expense would have to be incurred in changing the hydrants belonging to the companies. I should be very glad indeed, if I were a contractor, to undertake to change those hydrants at 2*l.* a piece instead of 10*l.* My estimate is based upon the new fire-cock which has been introduced in about 150 different towns. It is a cheaper thing than Captain Shaw's. It has been used for 18 years, and answers perfectly. My estimate included the cost of digging up and relaying the road—everything. I have changed hundreds of them, from the old wooden plug, in Manchester, to one on a better construction, at a cost not exceeding 30*s.*; that includes the fire-cock itself, the attachment of it to the pipe, and the box—the street casing which covers it and protects it from injury. It goes by the name of Bateman and Moore's patent. The patent has long run out. It consists of a vertical pipe coming from the main or from a side branch with a swelled part, in which a gutta-percha ball rises with the water and closes against the outlet; it has then two lugs rising from the mouth which enable a vertical pipe, called a stand-pipe, to be introduced and attached, and then by screwing down a handle which has a cup at the foot of it, which fits the top of the ball, the ball is depressed, the water rises round the ball in the swelled part, passes up the hollow stand-pipe, and so through the hose, and is thrown upon the fire. They are scarcely ever out of repair, and the attachment is simple. A certain head of water is required to make them available for putting out a fire. Where there is pressure enough you can do without fire-engines. Some 150 to 200 feet pressure is sufficient to avoid the necessity for fire-engines."

With regard to the constant supply in respect of water in the case of fires, Mr. Easton says; "I can give you the results of our practice at Brighton, which I think is about as well supplied a town in case of fire as any in the kingdom. All the mains and service-pipes are constantly charged of course, because we are obliged to give constant service into the houses. Every fire-cock is provided with a screw, to which the hose can be attached, and the hose-pipes are kept at the police stations. The turncocks have nothing to do with it, and we do not know or care when a fire takes place. A policeman goes to the hydrant and sees to it. The natural place to go to when a fire is discovered is the police station. They have there a large reel with the hose rolled upon it; they wheel it away to the place where the fire is, and with a key which they have with them screw it on in two minutes, and there is a pressure which will send the water over any house in

Brighton. They have no fire-engines in Brighton. We have a very efficient police, and they do the whole work of the fire business. We have nothing to do with it. We object to having the hydrant over the main; it is put just inside the kerb, if we have a right of prescribing it. Any one can see it there."

"In the case of Brighton you can screw it direct on to the hydrants, and then there is another spindle by which you can open the valve. The cost, including the branch to the main, the cutting of the main, and the putting the branch on is about 3*l*. 10*s*. each. In many cases in London you would require to have much larger ones, because the steam fire-engines use a great deal more water. I think the best would be the common sluice-cock, and a simple branch with a screw to it. You could put that in either 4, or 5, or 6 inches, as the case may be. The diameter of ours is 3 inches. I think I may have under-stated the cost for London—4*l*. would be about it for the whole, including the relaying of the road and the pavement. The relaying of the road in London is an expensive item. That is independent of the stand-pipe, which would cost as much as 3*l*.; it depends upon its length and the copper holes, and so on."

In the above pages we have called attention to the various features of large or small catchment basins, which particularly require the attention of an engineer, and which should guide him as regards the distribution of rain, stream and river gauges.

We have examined also the subject of obtaining town supplies from the chalk formation, because we believe that in many instances large supplies are to be obtained from this source. The Kent Waterworks are evidence of what may be done in this way; they are at the expense of pumping all their waters, but this is the case as regards rivers, in which there is besides the large additional outlay required for the construction of reservoirs and filters. Some care has also been taken to investigate the question of the deterioration of river water by organic matter, and of the manner in which this is remedied by nature during the course of the flow of streams.

We have also inquired into the subject of the manner and means by which several large towns are supplied, and we have endeavoured to give, as clearly as we could ascertain, the opinions of some of the most eminent hydraulic engineers of the day, viz.: Messrs. Bateman, Greaves, Hack, Morris, Muir, Quick, Simpson, &c. &c. Their opinions are of the highest value to the engineer who is investigating the details of house supplies under the intermittent and the constant supplies. We have not considered it necessary to say anything about pumps, because the subject has been exhausted in the columns of "ENGINEERING."

CHAPTER III.

Gauging Streams—The Discharge of Water in Overfalls—Rectangular and Triangular Notches.

In the first volume of the Practice of "Engineering Field Work" we have given a very complete description of the construction and setting up of overfalls for gauging streams; leaving, therefore, that portion of the subject untouched, we shall merely call attention to Professor Thomson's introduction of the triangular or V notch.

The ordinary rectangular notches, accurately experimented on as they have been at great cost and an eminent degree of scientific skill in various countries, with the view of determining the necessary formulas and coefficients for their application in practice, are for many purposes suitable and convenient.

They are, however, but ill adapted for the measurement of very variable quantities of water, such as commonly occur to the engineer to be gauged in rivers and streams. If the rectangular notch is made wide enough to allow the water to pass in flood times, it must be so wide that for long periods, in moderately dry weather, the water flows so shallow over the crest that its indication cannot be relied on. This, at least, will be the case unless the overfall is set up in seasons of drought. In the rectangular notches the parallelograms are dissimilar for every varying depth of water, but for the triangular notch the triangles are always similar.

To remove, in some degree, this objection, gauges for rivers or streams are sometimes formed in the best engineering practice with a small rectangular notch cut down below the general level of the crest of the large rectangular notch.

If now, instead of one depression being made for dry weather, we use a crest wide enough for use in floods, we may conceive a large number of depressions extending so as to give the crest the appearance of a set of steps of stairs; and if we conceive the number of such steps to become infinitely great, we are led at once to the conception of a triangular instead of a rectangular notch.

The principle of the triangular notch being thus arrived at, it becomes evident that there is no necessity for having one side of

the notch vertical and the other slanting; but that it may in many cases prove more convenient that both sides may be made slanting and their slopes alike.

It is then to be observed, that by the use of the triangular notch, with proper formulas and coefficients, derivable by due attention to theory and experience, quantities of running water from the smallest to the largest may be accurately gauged by their flow through the same notch.

The reason of this is obvious, from considering that in the triangular notch when the quantity flowing is very small, the flow is confined to a small space admitting of accurate measurement; and that the space for the flow of water increases as the quantity to be measured increases, but still continues such as to admit of accurate measurement.

Further, the ordinary rectangular notch, when applied for the gauging of rivers, is subject to a serious objection from the difficulty or impossibility of properly taking into account the influence of the bottom of the river on the flow of the water in the stream towards the notch. If it were practicable to dam up the river so deep that the water would flow through the notch as if coming from a reservoir of still water, the difficulty would not arise.

This, however, can seldom be done in practice, and although the bottom of the river may be so far below the crest as to produce but little effect on the flow of the water when the quantity flowing is small, yet when the quantity becomes great the velocity of approach comes to have a very material influence on the flow of the water, but an influence which is usually difficult to ascertain with satisfactory accuracy.

In the notches now proposed of the triangular form the influence of the bottom may be rendered definite, and such as to affect alike (or at least by some law that may be readily determined by experiment) the flow of the water when very small, or when very great, in the same notch.

The method by which Professor Thomson proposes that this may be effected consists in carrying out a floor, starting exactly from the vertex of the notch, so as to form a bottom for the channel of approach, both up-stream and laterally, which will both be smooth, and will serve as the lower bounding surface of a passage of approach unchanging in form while increasing in magnitude, at the places at least which are adjacent to the vertex of the notch.

The floor may be either perfectly level, or may consist of two slanting planes, whose intersection would start from the vertex of the notch, and would pass up stream perpendicularly to the

direction of the overfall; the two planes slanting upwards from their intersection more gently than the sides of the notch.

The level floor, although theoretically not quite so perfect as the floor with the two slanting planes, would probably be the most convenient arrangement for most practical purposes. Considering all the minor practical difficulties which arise in getting overfall well set in the streams to be gauged, there is no doubt that the level floor would be the most easily set up.

With reference to the use of the floor, it may be said, in short, that by a due arrangement of the notch and the floor, a discharge orifice and channel of approach may be produced, of which (the upper surface of the water being considered as the top of the channel and orifice) the forms will be as little changed as possible, with variations in the depth of water flowing over—very much less certainly than in the case of rectangular notches.

Whatever may be the result in this respect, the main object must be to obtain, for a moderate number of triangular notches of different forms, both with and without floors at the passage of approach, the necessary coefficients for the various forms of notches and approaches selected, and for various depths in any one of them, so as to allow of streams being gauged for practical purposes by means of similarly formed notches and approaches.

The utility of the proposed method of gauging will not depend upon a perfectly close agreement of theory with experiments, because a table of experimental coefficients for various depths, or an empirical formula modified from the theoretical one, will serve all purposes.

There is one evident, and very important and practical simplification in the method of stream gauging which Professor Thomson has proposed, and which has become very generally adopted; the quantity of water flowing comes to be a function of only one variable, namely, the measured head of water. In the rectangular notches it is a function of at least two variables, namely, the head of water and the horizontal width of the notch; and is frequently also a function of a third variable very difficult to be taken into account, namely, the depth from the crest of the notch to the bottom of the channel of approach, which depth must vary in its influence with all the varying ratios between it and the other two quantities of which the flow is a function.

The proposed system of gauging also gives facilities for taking another element into account, which often arises in practice, namely, the influence of backwater on the flow of the water on the gauge, when, as frequently occurs in rivers and streams, it is

found impracticable to dam up sufficiently high to give a clear overfall, free from the back or tail water.

For any given ratio of the height of the *tail* water above the vertex of the notch to the height of *head* of water above the vertex of the notch, Professor Thomson would anticipate that the quantities flowing would still be approximately, at least, proportional to the square root of the fifth power of the head, as before; and a set of coefficients would have to be determined experimentally for different ratios of the height of the head of water to the height of tail water above the vertex of the notch.

Some preliminary experiments were made on a right-angled notch in a vertical plane surface, the sides of the notch making angles of 45° with the horizon, and the flow being from a wide and deep pool of quiet water, the water thus approaching the notch uninfluenced by any floor or bottom. The experiments were made on quantities of water varying from about 2 to 10 cubic feet per minute, with heads of water varying from 2 to 4 inches in the right-angled notch.

From these experiments Professor Thomson derived the following formula:—

$$Q = 0{\cdot}317\ H^{\frac{5}{2}}$$

in which Q is the quantity of water in *cubic feet* per minute; and H the *head in inches* measured vertically from the still-water level of the pool down to the vertex of the notch.

The above formula has only been submitted temporarily, as being accurate enough for use for ordinary practical purposes for the measurement of water by notches similar to the one experimented on, and for quantities of water limited to nearly the same range as those in the experiments.

There can be no doubt that in practice for stream gauging the above formula and the triangular notched overfall are exceedingly convenient, as there are in reality no calculations to make when once a table of the square root of fifth powers has been calculated. Where there are numerous gauges, perhaps a dozen or more, over some square miles of country to be gauged as often as possible in the course of every four-and-twenty hours, there is a great difficulty in obtaining strictly accurate results. To approximate to this it would require for some trustworthy observer to be constantly on the watch at every overfall; a passing shower, a lump of weeds, or a small branch of a tree may get temporarily entangled on the crest of the notch, and vitiate gaugings otherwise made with the greatest care.

Mr. Neville, the eminent authority on Hydraulics, makes the following observations on this subject in the second edition of "Hydraulic Tables, &c."

"The disadvantage of the proposed triangular form of depression, if permanent in a dam, would be that the angular point should be at a lower level than the top of a horizontal crest to maintain the same level above, of the water during floods, and therefore the power of the water and head would be reduced at the period when most required for mill power or navigation purposes, that is, during dry weather. For drainage purposes the winter level or that during floods, must evidently be kept down, unless where the banks are steep and along rapids; but these remarks do not apply to dams erected across mill races or streams, where the banks are generally considerably above floods. These remarks refer to occasions for permanent gauging to find the relations of evaporation, absorption, and discharge in given catchment areas."

PIPE FORMULAS.

PRONY'S FORMULA.

$$V = 48{\cdot}449\sqrt{\frac{DH}{L}}$$

EYTELWEIN'S FORMULA.

$$V = 45{\cdot}5\sqrt{\frac{DH}{L + 47\ D}}$$

PONCELET'S FORMULA.

$$V = 47{\cdot}95\sqrt{\frac{DH}{L + 54\ D}}$$

MR. SIMPSON'S FORMULA.

$$V = 50\sqrt{\frac{DH}{L + 50\ D}}$$

V, velocity in feet per second.
D, diameter in feet.
H, head in feet.
L, length in feet.

CHAPTER IV.

SEWERS.

NOTWITHSTANDING all that has been executed in the shape of constructed works, and all that has been written about works of sewerage, there still exists a great amount of difference of opinion as to the forms and dimensions of sewers, the materials of which they should be constructed, and the depths at which they should be laid below the surface.

In one position a brick sewer 5 feet by 3 feet will be constructed at from 2*l*. to 3*l*. per lineal yard, whilst in a similar situation an earthenware pipe of 1 foot 3 inches in diameter will be laid with the intention of effecting the same purpose at an expense of from 7*s*. to 11*s*. per lineal yard. Here is great discrepancy in professional practice, and in such cases there is a probability that both practitioners are in error from having adopted extreme views.

"If that man is a benefactor to his race, who makes two blades of wheat grow where only one grew before, he is so likewise who constructs two lineal yards of effective sewer for the price that has been expended upon one yard."

It has been said that every street sewer should be constructed of sufficient size to allow a man to go into it for purposes of inspection; but this will depend in a great measure upon the situation and conditions of such sewer.

Amongst the principal considerations respecting sewers we have the following:—

1st. The dimensions and the forms of outlet sewers.

2nd. The materials of which sewers may be constructed.

3rd. The line for the outlet sewers.

The size of outlet sewers will depend upon the number of houses to be drained, the extent of area upon which they are built, and the quantities of surface drainage they are designed to carry off; and therefore as regards the last consideration the dimensions of sewers will depend more or less upon any use to be made of the sewage matter for agricultural purposes.

We may or we may not have to make use of the sewage, and in this respect the engineer is often placed, in foreign climates particularly, in a different position to that which he now occupies at home, in regard to the future non-pollution of rivers.

Where sewage matter is not to be applied to agricultural pur-

poses, conditions may exist where it is not undesirable that the storm-waters should be made available to a reasonable extent for the purpose of flushing and cleansing the sewers. In our observations regarding works of sewerage we shall endeavour to keep in view the position of the engineer, when abroad as well as at home.

The position of the outlet or outfall of sewers will be governed by natural conditions, but they must always be in such position as will least endanger health, more particularly where the sewage is not to be made available, but is allowed to go to waste, however undesirable this may be.

Generally, and where possible, only one outfall is adopted, for purposes of economy and the concentration of the sewage for natural removal or agricultural use.

The site to be drained may consist of flat alluvial land; it may be on the banks of a tidal river with the surface but little above, or perhaps considerably below, the level of high water-mark spring tides. The soil may be impervious, or it may consist of sand and gravel. To go to the other extreme as regards situation, the site instead of being a low flat level may be on the side of a hill; hence arise conditions so very dissimilar that the works of sewerage cannot be much alike.

The site to be drained may consist partially of a flat plain, and partially of rising land with a straight flat slope; or this may be convex or concave in its fall towards the plain, which will at once offer different conditions to satisfy.

The land may rise on both sides as from a creek, or there may be several creeks or basins with natural watercourses passing through them, bringing down the surface waters of suburban districts much larger or smaller than the house districts; these and many other combinations may arise, requiring to be treated more or less in a different manner. Each case will require special study and attention to the differences in the localities.

Some of the conditions may be as to whether the sewers are to carry away the storm-waters, or some portions of them, the latter being the case generally. Generally also the sewers ought not to be combined with natural watercourses which drain large areas of suburban lands previous to entering the town portions of the district. As much as possible the sewers should be adapted exclusively for removing all liquid and solid refuse from the houses in a manner to cause the least possible nuisance to the population.

When the situation of a town is a plain, only little elevated above the tidal water line, the delivery of the refuse from sewers must either be by pumping to render it constant, or it must be

intermittent, and therefore leaving the refuse for a time stagnant in its channels of conveyance.

Sewers and drains are frequently required in situations where high tides, land floods, or both combined, cover to a considerable depth the surface beneath which such sewers must be laid; or if the area is embanked the waters rise above the level of the land and of the outlet. These circumstances frequently serve as excuses for not attempting the forming of any works of sewerage or drainage, and it is often much safer to the inhabitants that there should be no sewers, than that these should be constructed for sewers of deposit.

That towns so situated may, however, be perfectly and even economically drained, is proved by the condition of Holland, where very commonly the land is below the level of the sea, although it is one of the most densely populated countries in Europe.

In England, large portions of Lincolnshire, Cambridgeshire, and other counties with large areas of agricultural land only worth from 100*l.* to 200*l.* per acre, and even less, are drained either by intermittent action, or to a great extent by pumping machinery.

That which is done profitably for agricultural purposes should generally be carried out satisfactorily for town sites, where the intrinsic value of the land and property is ten or a hundred fold more valuable, setting aside the importance of the sanitary question.

It may certainly be considered that town sites may be drained profitably by pumping on account of the additional value given to property, and independently of the profit that may or may not be derived from the sewage for manure purposes.

When a town site is partially a plain, and partially rising ground sloping towards the lower levels, the formation of intercepting lines of sewers to receive the contents of the sewers and drains of the higher portions, and to prevent their falling into the lower level, may save much pumping.

Generally the sewers formed in level or low districts may be of minimum dimensions, and they should be laid as near the surface as is consistent with their safety. They should be constructed of materials capable of resisting external pressure without crushing, and internal pressure without leaking or bursting.

If sewers in connexion with pumping machinery are much larger with the pumping powers employed, the current through them will be sluggish, and deposits will form, which it may afterwards be inconvenient to remove. Such sewers should not be unnecessarily deep, in order that the lift for the pumps should be

reduced to a minimum, and they should be capable of resisting hydraulic pressure, as they may be liable to be filled above the soffit, either through an extraordinary rise of tide or through heavy land floods.

This latter consideration may involve the consideration of sluices or valves. Sewers in flat districts may be made of minimum dimensions, other conditions however being allowed for, because in such situations extraordinary floods cannot be provided for by the sewers. Tides regularly, and rivers irregularly, may rise some fifteen or twenty feet, and flood many square miles of land. In such districts, large sewers may offer no benefit, and in very dry weather may and will probably be very noxious.

The areas drained by natural watercourses may be much larger than that of the town area, and therefore any aqueduct-pipe or sewer to convey away safely the flood waters of such a district must be in proportion to such area. The cost is in proportion to the circumference of the aqueduct formed. Another consideration which should be duly attended to is that the flow of flood waters is intermittent, whilst the flow of sewage should be constant; that is, the sewers should be as much as possible self-cleansing by means of the daily action of the fluids passing through them. This cannot be the case if a shallow body of water is spread out over a wide bottom or invert. There must be in such a case a deposit, which generally will be increased by such obstructions as stones, grit, or more than ordinarily solid refuse from the houses. All sorts of substances may be carried from the open watercourses into all sewers receiving the flood-waters of a suburban district, because the channel leading to the sewer and the end of the sewer itself must be open.

The stagnation of sewage in such places will also be greatest during the driest period of the year, when the gases evolved will be most injurious.

On the other hand, it must not be lost sight of that in extensive and flat urban districts, where it is not possible or where it may be difficult to obtain such differences of level in the sewers as will cause an efficient velocity in the run of water, advantage may be taken of a stream situate at a somewhat higher level to obtain a flush in the driest portions of the year.

There may therefore be valid reasons against an invariable rule, that sewers, other than main outlets, under particular circumstances, should not be calculated to contain the flow of flood-waters of an excessive rainfall. Under such circumstance as that we have just above mentioned, pipe sewers may be more noxious than brick sewers, which would be large enough to carry a depth of water sufficient for flushing purposes, and which

quantity of water might damage pipe sewers in which refuse matter had solidified.

A rainfall of two inches in depth in one hour is not a very unusual occurrence, and a fall of 1·94 in depth will give about 44,000 gallons per acre; although this is not frequent, it has occurred too often in several parts of England to be lost sight of. Those who have any given area to drain may make use of the multiplier 22,506 for every inch depth of rainfall in ascertaining the maximum amount per acre to be carried, when it is premised that sewers ought to be of sufficient capacity to carry off flood-waters, or any portions of them. In many cases the storm waters will flow off the surface in the same manner as they were discharged before the construction of the sewers.

The dimensions of sewers may in some measure determine their depths below the surface, as there should be a fall of about 1 in 50 to 1 in 70 from the lowest level of a house to the highest water line to which a sewer may be allowed to fill.

Many of the following subjects will have to be investigated before a design of the sewerage of a town can be completed:—

1st. Existing surface works, such as streets and roads, to facilitate or impede the free discharge of rain water.

2nd. The existing effects experienced by land floods, and the manner in which they are carried off.

3rd. The practicability of constructing sewers sufficiently capacious to carry off the whole or a portion of the heaviest rainfall, at such a level that they shall not inconvenience the low levels of houses by back water.

4th. The additional length of outlet where it can be obtained, and which may be required to secure a fall for deeply-laid sewers.

5th. The application or disposal of the sewage.

The engineer will often meet with situations where houses ought never to have been built, and where the natural outlets have been destroyed or contracted. In such cases he will have to examine all the local features, and study how far he can make use of them, and avoid making use of any forcibly controlling powers.

In designing any system of sewers, we must almost always examine how far we can facilitate and make use of existing operations of nature. This is very generally one of the first things to be done. It by no means follows that because the whole of a town has to be sewered one of the first things to be done is to construct a large sewer at a great depth below the surface, which would very often damage or destroy the natural outlet.

Where it is decided that sewers are not to convey away the drainage waters of suburban districts, and further even, that they

are not to be made of sufficient capacity to contain even the urban rainfall during maximum rain floods, we shall have to decide of what dimensions the sewers should be. Generally speaking, however, it is the combined question which will have to be considered.

But if for house and yard drainage only, a case which we consider will arise in future more frequently than it has arisen in the past, there will at once be reliable data from which to calculate the dimensions of the sewers.

The sewers and drains will then be of the minimum safe size, and will consequently not require either very wide or very deep excavations, and the cost of the works will be reduced to a minimum also.

It will be admitted that many large sewers were not originally constructed to serve the purpose to which recent practice has adapted them, namely, to receive and carry away the contents of waterclosets for an entire population; and there are still in many towns in England great lengths of sewers which do not receive the refuse of the adjacent houses.

In discussing the best forms for sewers it is necessary to consider their capacities and the materials of which they can be most advantageously and economically constructed, due attention being paid to all circumstances of the locality. Generally it will be necessary in the first place to examine the nature of the subsoil before either the form or materials of the sewers can be finally decided upon, and the engineer may frequently find that after his design has been completed both form and materials have to be modified in order to overcome some natural difficulties which could not be previously ascertained: such circumstances may often cause considerable alterations in the original design, and frequently, even, they may cause partial failures with the best of us.

"In existing sewers and drains may be found almost every sectional form of which such constructions are capable; they are V-shaped, square, oval, and circular, and also partake of every intermediate combination of these figures. V-bottoms have been defended, flat floors or inverts have been advocated, and the egg-shape has been insisted on, even for drains down to 4 inches in diameter. There have been as varied assertions made relative to diameters."

It has been asserted that sewers having a transverse sectional width of more than 2 feet should have a *circular* invert, in order that the minimum flow of water may be concentrated.

For sewers less than 2 feet in diameter, the strongest form is the circle, whether they be constructed of pipes or bricks. There

is an advantage in the egg-shape when sewers exceed 2 feet in diameter, but practically that form possesses none for lesser dimensions, and should not in practice be adopted for small sewers or drains.

In the Holborn and Finsbury divisions, Mr. Roe calculated that an 18-inch cylindrical pipe laid at an inclination of one in eighty is sufficient for 20 acres of house sewage, while a 5-inch pipe laid at an inclination of one in twenty is necessary for one acre, and a 3-inch pipe, laid also at one in twenty, for a quarter of an acre. A pipe of 30 inches in diameter, laid at an inclination of 1 in 200, would discharge 1700 cubic feet per minute, and perfectly drain 200 acres of urban land covered with houses to the extent of 4000 or upwards, and each house having a water supply of 150 gallons per day. In every case, however, the discharge from each pipe must depend upon its head and length, as well as the inclination at which it is laid.

According to the opinion of Mr. Roe, who was for a long time surveyor of the Holborn and Finsbury districts of sewers, the cost of cleansing small drains was greater than the expense of constructing an efficient sewer; he thought that no amount of water sufficed to cleanse a small pipe-drain when it became stopped; but that in a large sewer flushing and other means could be effectually adopted without any inconvenience being experienced on the surface.

In one of his reports he says, "the desire of some persons to effect a further saving has led to the advocacy of drains or small sewers to be placed in streets or roads, without discrimination. Others advocate two lines of small sewers, or pipes, one on each side of a street to receive the drainage; but as two such small sewers would not carry off the surface drainage in all cases, other parties consider that one line of sewer should be formed for the surface, and another for the house drainage. In practice this would be found unnecessary as regards any advantage to the sewer water for manure, and as regards expense it would, besides causing an immediate extra expense, entail a perpetual annoyance and charge. A fact that will serve to illustrate this is that of the new sewer lately built in Hoxton Town. On each side of Hoxton there was a line of small sewers in front of the houses; the cleansing of these and of other small sewers have cost on an average 1*s.* 3*d.* per foot lineal each time of cleansing. Taking 15 such sewers, the average time of cleansing has been four years and a half; and reckoning the first cost of the two small sewers with the cleansing, the cost in about twenty years would have amounted to the expense of constructing an efficient sewer. This commission has caused a new sewer to be built in Hoxton

Town, which will require no repairs for more than a century. The saving to the public therefore by constructing an adequate sewer, and doing away with the two inefficient ones, will be double the amount which the new sewer has cost. After many years' experience your surveyor begs to state that, except a sewer has an extraordinary inclination, or has a body of water passing along it with a considerable velocity, deposits will accumulate. If a small sewer or drain be choked with filth, no water will wash it clear; but the deposit must be raised and removed by manual labour; but if 2 or 3 feet in depth of deposit is accumulated in a sewer large enough for a man to pass through, the new sewers ranging from 3 feet 6 inches to 5 feet in height in the street, such deposits could be washed away in the manner adopted in your own sewers. I would observe generally that, in an extensive drainage, it will be found ultimately a saving to the public to make them large enough for a man to pass through them occasionally, except when the inclination is so great, and the supply of water so plentiful, as to ensure these never requiring them to be opened."

Sewage cannot be considered merely as water, and in most cases sewers require occasionally flushing or manual cleansing. The dimensions of sewers can scarcely with safety be calculated as though they had nothing to convey but clear water. The sewage matter often lies at the bottom of the sewer, and is very frequently deposited there, while the water flows on over it, only carrying away diluted and detached portions.

Where, therefore, manual cleansing or artificial flushing are not provided an allowance should be made for some portion of storm-waters passing through the sewers, particularly the main outlets.

On the subject of the drainage of a country town of 1500 acres having been drained by a twenty-inch outlet pipe, we will quote a few more opinions from Mr. Roe, because however much different conditions may alter modes of proceeding, we have a great respect for his experience and abilities. "I have observed twenty-five cubic feet of water per minute per acre reach the sewers from an inch fall of rain in the hour from a surface where the houses have much garden ground attached; and in another case where the houses were nearer together, thirty-three cubic feet per minute. To pass the latter quantity of water through a twenty-inch pipe there must of necessity be a velocity of current exceeding four miles per minute, or 240 miles per hour; and if more than a fall of one inch per hour be expected, the velocity will need to be increased accordingly. That greater falls of rain do take place, and that not unfrequently, is a well-known fact.

I have known ten instances of the kind during the period of my observations in the Holborn and Finsbury sewers. An instance is given of a two-inch rainfall in Birmingham in little more than half-an-hour, and there was a main sewer which a rainfall had filled to within three inches of the roof, the area draining to it not exceeding 700 acres; yet the transverse section of that sewer had an area of very nearly eight times larger than the twenty-inch pipe, which was considered ample for the drainage of 1500 acres."

"There will be few localities whose outlets for drainage will be so situated as to afford in every instance such an inclination or fall to the sewers as would enable occasional rains to clear them from deposit; and the water from the common house drainage would prove of little use for such purpose unless dammed up for flushing; the cost to supply water sufficient to keep a constant stream, as has been suggested in some cases, would soon amount to more than the expense of a proper-sized sewer, and the keeping it flushed in the ordinary way. In August last the surveyor had occasion to report that four inches in depth of rain had fallen in one hour on the first of that month; a circumstance that cannot be too extensively known at a time when much sewer work is likely to be executed in this country; for having once experienced such a fall of rain, it is right to expect and provide for the like occurrence in future."

As regards the flow of water in circular pipe-drains and egg-shaped brick sewers, it may be argued that in a pipe-drain of twelve inches in diameter, conveying only such a quantity of water as would half fill it, or make the stream six inches deep, and compared with it an egg-shaped brick sewer whose bottom was formed to a radius of six inches, and whose sides widened gradually upwards to a sufficient height for admitting a man to pass along; in such a case it may be contended that at similar inclinations a stream of water, also six inches deep, would flow as freely at least in the brick sewer as in the pipe-drain; and that when the stream filled up the entire area of the pipe-drain the same quantity of water would pass more freely through the brick sewer on account of there being less lateral friction, and there being a greater hydraulic mean depth. This was self-evident, and proved that if a proper sectional form was adopted for the large sewers a small quantity of water was as effective in them as in pipe-drains, with the additional advantage of providing for sudden falls of rain, for accidental stoppages, and for the contents of the sewers being ponded up.

"Suppose the case of the south side of the Thames, where a part of the land was below low water mark, and consequently where

there was a stoppage by the tide of the discharge from the sewers for sixteen hours out of every twenty-four hours; if the dimensions of the sewers were reduced by rule to just the sectional area calculated for the discharge, and no provision was made for accumulation for the period of inactivity, the contents of the pipe-drains must either be forced back up into the cellars and basements, or the pipe-drains must be burst.

"This would not occur under ordinary circumstances with proper sized sewers, and after careful consideration of the subject we may, at least under many circumstances, arrive at the conviction that there was danger and inconvenience, as well as extra cost, to be apprehended from the indiscriminate and too general employment of small pipe-drains, although they are applicable to special localities and purposes."

The ultimate expense of maintaining sewers should be as much considered as the first cost, and the drainage of a town cannot be considered as properly executed if it is not an enduring as well as an effective work.

Instances have been given of towns being well drained for a time, but when the stoppages once commence there is no telling to what extent the expense or the public inconvenience may extend.

It may be admitted that a brick sewer of thirty-six inches in diameter is in some localities as cheap as a pipe-drain of twenty-four inches diameter, and that it is not liable to the same casualties of fracture or crushing.

There cannot be a doubt in many situations as to which should be adopted; it must be admitted that permanency and durability must be amongst our first considerations in designing a work of sewage, and it is stated on good authority that at sharp inclinations the abrading action of the grit on the bottom of pipes, or even on ordinary bricks, would soon wear them away.

One of our most eminent hydraulic authorities first pointed the following facts, as regards the flow of water in cylindrical pipes. It may be observed in numerous experiments that water does not entirely fill the orifice of exit when the velocities are not considerable, and yet the results are found to be but slightly affected if a little more than three-fourths of the circumference be full.

It is easy to demonstrate that the full circle does not give the maximum discharging velocity as has been generally believed, but when filled to the height of the upper chords of an arc of 78½ degrees, and where the velocity is 9½ per cent. over that due to the full circle, for then the area of the lower segment divided by the arc of the upper is a maximum, and the length of the arc of the lower segment is equal to the tangent of the supplementary arc.

The hydraulic mean depths of the circle and larger segment are to each other as ·5 to ·6, and their square roots which are as the velocities, or scouring powers, are as 1 to 1·095. The discharging powers are to each other as 1 × 3·1416 to 1·095 × 2·946, or as 1 to 1·026, which shows that the lower segment above referred to has also a greater discharging power than the whole circle of nearly 3 per cent. The effects of greater velocity and discharge here pointed out are sometimes increased in short pipes from the fall between the chord of the upper arc and the surface from which the head is measured being greater than the fall to the top of the pipe, or from the inclination of the surface of the water in the pipe being greater than the inclination of the pipe itself.

The amount of sewage per head per day has been very variously estimated from 3½ to 7 and even 8 cubic feet. It has been found, and generally allowed, that about half the estimated quantity passes off in about six or eight hours.

In calculating the size of sewers the rainfall has to be considered in addition to the sewage from dwelling houses and trading establishments. Mr. Bazalgette calculated for the London sewage ¼-inch rainfall per 24 hours in the urban districts, and ⅛ of an inch for the suburban districts. Messrs. Simpson and Blackwell and Captain Galton assumed ⅔ of an inch fall during eight hours' maximum flow, which would give 1452 cubic feet per acre.

Assuming the highest quantities, we shall have to provide sewers to discharge in eight hours 1452 cubic feet of rain per acre, and 3½ cubic feet nearly of sewage per head of population. If the latter be taken at 80 per acre, and the discharge to take place in eight hours, we shall have 1452 plus 280, or about 3½ cubic feet per acre per minute. From this we may deduce that the sewage is about ⅕ of the rain water. This includes only a very small rainfall in twenty-four hours.

It may also be considered that the amount of sewage per head varies with the peculiarities of different towns, and also in different parts of the same town. In the more thickly inhabited portions of London the daily amount of sewage has been estimated at 4·8 cubic feet per head, whilst in the western district, inhabited by the wealthier classes, it is estimated at as much as 8 cubic feet per head, and the average of the whole of London is a little less than 6 cubic feet per head.

In these matters it is very usual to divide the day into three periods of eight hours each; the amount of maximum flow is taken as between 7 A.M. and 3 P.M., and 9 A.M. and 5 P.M., according to the habits of the population, and to amount to 49

per cent. of the whole; the minimum flow, which takes place in the night, is taken at 18 per cent. of the whole.

We are very far from advocating any indiscriminate use of either large or small pipe-drains, but we venture to think that they may render good service in many cases, and this we venture to observe, notwithstanding all that has been said for and against them; in the latter there may be some little animus, most deservedly called for, however, by the fallacies promulgated under authority; but this is now some years since.

Of course we all know that the failures of sewers constructed of earthenware pipes have been more than sufficiently numerous, but perhaps something may be allowed for very indifferent materials, and certainly for a good deal of very bad workmanship in laying. In England it is very possible that the pipe system, we mean earthenware, is effectually condemned, at any rate for some time to come; but abroad we cannot help thinking that if properly made, of sufficient thickness and of good material, and if well laid, they may be made very useful in matters of sewage and waterworks. We have seen towns supplied with water with materials very inferior to our earthenware pipes. For large towns, pipes cannot be thought of favourably as street sewers; in small towns it may be quite different.

Pipe sewers of earthenware have been made from 3 inches to 36 inches in diameter; the first were probably made to satisfy dreamers, at least in sewage matters; the latter size is too large for the nature of the material, with exceptions however, as also for the thickness of which these pipes are generally made to consist.

Mr. Doulton in order to satisfy himself as to the strength of well-made pipes has caused a series of trials to be made of more severe character than tubes will ever be subjected to practically.

The pipes experimented on were 2 feet long, and each pipe was supported at the ends on blocks; a piece of wood 12 inches long was laid on the middle, and the weight was gradually increased until fracture ensued. The following table shows the result:—

Diameter of Pipes. Inches.	Thickness. Inches.	Weight on 12 inches square Broke. Cwt.	qrs.	Weight over the entire surface of the Pipe. Tons.	cwt.	qrs.
18	$\frac{7}{8}$ $\frac{1}{16}$	53	3	14	2	1
15	$\frac{7}{8}$	31	3	7	1	1
12	$\frac{3}{4}$ $\frac{1}{16}$	53	3	8	13	2
12	$\frac{3}{4}$ $\frac{1}{16}$	71	0	12	12	0
9	$\frac{3}{4}$	64	3	8	18	3

Mr. Donaldson, who had a large experience as to earthenware pipes, gave the following proportions:—

TABLE OF THICKNESSES.

Diameter of Pipes	$6\frac{3}{4}$	$8\frac{1}{8}$	$10\frac{1}{2}$	$12\frac{1}{2}$	$13\frac{5}{8}$	$14\frac{7}{8}$	inches.
Thickness .	$\frac{5}{8}$	$\frac{3}{4}$	1	$1\frac{1}{4}$	$1\frac{3}{8}$	$1\frac{1}{2}$	inch.

And he considered that as a general rule the thickness of substance should not be less than one-tenth of the diameter of the pipe.

Mr. Joseph Cliff has made considerable quantities of large sized pipes or tubes at the Wortley Firebrick Works for the drainage of the towns in the district. The pipes were generally egg or oval shaped, and the largest sizes were 20 inches by 15 inches, 25 inches by 18 inches, and 30 inches by 21 inches.

Of this latter size nearly 7000 yards had been already laid down in the streets of Leeds since the drainage commenced. In consequence of a doubt as to the advisability of the system of pipe sewerage, men had been sent up the sewers to examine them, and to report upon their condition. They had been exposed in many parts to the heavy traffic of the streets, and the heavy rains having caused subsidence of the ground in the trenches, and in several instances filled the pipes themselves full of water, they had been as severely tried as it seemed probable they ever could be.

After a minute investigation the pipes were found sound and good, and not one single failure was discovered in the whole line, which had the appearance of being self-cleansing.

These pipes were made of a strong metallic fire-clay, which by resisting an intense heat in the kiln allowed the inner and outer surfaces to be vitrified, and to receive a good glaze, still retaining their shape and not splitting or cracking in cooling. They were made about $2\frac{1}{4}$ inches in thickness, and if it was found by experience that greater strength was required, there could be no difficulty in making them thicker.

Those used in Leeds were all socket-pipes, whilst those laid in Manchester and that neighbourhood had only plain butt joints. The great and indiscriminate objection to the use of all pipe sewerage may arise to some extent from the sizes, nature, and thickness of pipes which have not answered the purposes for which they were made.

"It was impossible to make the London pipes of the sizes and thickness mentioned, the quality of the clay forbidding it, and appearing to involve the necessity of their being made thin, and merely as pottery ware, and therefore possessing the ordinary

characteristics of pottery ware, liability to snap or break by sudden concussion or heavy pressure. Large sizes of the necessary strength could not therefore be made from London clay. In the Leeds district, however, there was not any difficulty of making pipes of almost any size, and strong enough to bear any external pressure. The pipes mentioned were made under pressure by Spencer's machine, the socket being made at the same time, and not being put on afterwards as was often the case. If required still larger, pipes could be made up to 36 inches, and of any requisite thickness. Mr. H. Wrigg had used large quantities of these pipes at Preston, and he preferred having them of circular section, giving to them the dimensions of $\frac{1}{8}$-inch in thickness for each inch in the diameter of the pipe; thus a pipe of 24 inches in diameter would be 3 inches thick. It might be considered as a fact, that oval pipes could be made even up as high as 3 feet by 2 feet 4 inches, and of proportionate thickness without difficulty."

The surveyor of the paving and sewering department of Manchester supplied some valuable information on this subject. He stated that the main or street drains were laid at various depths from 9 to 30 feet; the passage and branch drains to all depths from 2 to 10 feet.

The ordinary inclination for main drains was $\frac{1}{4}$ inch per yard, although a few are laid on at rather less inclinations. For house drains the inclination was made 1 inch per yard, or even more.

The largest sized pipe was 25 inches by 18 inches.

The largest area drained into a pipe-drain was about 50 acres. For small areas the dimensions of the pipes were adapted in excess of the formula, but greater exactness was observed for the larger areas.

It was considered that there was a principle inimical to the use of very small pipes for the discharge of foul water loaded with matter more or less solid, viz.—the ratio of the periphery to the transverse area increases inversely to the size, so therefore also the friction and the liability to stoppage.

They had no sockets to their oval tubes, but have them round the cylindrical pipes which formed the vertical shafts connecting the surface with the main drains; to the rejection of the sockets was attributed the immunity from breakages.

The surveyor to the borough of Salford had not used any pipes of less dimensions than 6 inches by $4\frac{1}{2}$ inches, nor larger than 12 inches by 9 inches, and those only for conveying the surface water from courtyards, passages and streets, into the egg-shaped main sewers which were built of brickwork, and varied in size from 42 inches high and 32 inches wide, down to 24 inches high

by 18 inches wide. It was even broadly stated by men who appeared to have experience that the pipe-drain system had been carried to an extent in Manchester which would eventually cause serious inconvenience.

In the construction of pipe sewers it is important that the proper position for all the house drains to be previously well ascertained, so that the junctions and branches for their reception may be properly placed, and these ought to be marked so as to be readily found when wanted, and to avoid mistakes in opening the ground at wrong places. A great part of the pipes for the main sewers at Richmond being of unusual sizes, with sockets somewhat larger than usual, were made to order, and no pipe was allowed to be used until inspected and approved of.

On being laid the joints of the pipes were rammed first with well-tempered clay to one-third the depth of the socket, above which the joint was made good with cement, the sockets being purposely made somewhat longer than usual, and great care was taken to pack the earth solidly about the pipes so as to support them laterally against the crushing pressure of the overlying earth. This is a very important, and it may be added difficult part of the work in constructing pipe sewers, particularly in closely timbered trenches, where in drawing out the timbers a vacancy is apt to be left alongside the pipes, which renders them more liable to be crushed by the weight above them. In cutting the trenches various qualities of ground are to be met with; in some parts of solid clay; in others a sharp dry sand; in others a sand full of water; in some places a slipping clay intersected by numerous veins of sand full of water.

Earthenware pipes may be used for house drains, and often for courts and alleys, and even in some cases for short street sewers where new junctions for house drains are not likely to become necessary. The frequent breaking open of a pipe sewer for the purpose of connecting additional house drains very soon occasions its entire destruction; and the constant lifting of the pavement for such purposes is a cause of much of the annoyance and expense complained of in the use of pipe sewers.

As regards economy of construction, it is generally admitted that a pipe sewer of 18 inches or 24 inches in diameter is much more expensive in most cases than a brick sewer of similar dimensions, and that the cost of sewers does not increase in proportion to the sectional areas, but as the circumferences. For instance, a circular sewer of 3 feet 6 inches in diameter has a sectional area of 9½ feet, its circumference being 11 feet, while one of 4 feet diameter has an area of 12½ feet, its circumference being also 12½ feet. The difference between the sectional areas of the

two sewers is 8 feet, but their difference in brickwork is only 1½ feet.

Again, the difference between a sewer of 4 feet and one 6 feet diameter is 15 feet of area for 6 feet of brickwork; and in a circular sewer of 4 feet in diameter there is 1 foot of brickwork for each foot of sectional area; whilst in a sewer 8 feet in diameter there is only half a foot of brickwork for each foot of sectional area, and the difference in the cost of excavation is still less.

It appears very desirable to prevent as much as possible the road drift from entering the sewers, and this is to a great extent effected by the construction of catch pits, to which we shall have to refer hereafter.

With regard to the flushing of sewers, it must be kept in mind that the heavier matter held in suspension in the sewage, or driven along by the current, never moves with the same velocity as the water, and that consequently with intermittent currents, as in house drains, it is often left dry and becomes indurated, so that it cannot be moved by the succeeding flow of water; hence the imperative necessity of a continuous current of water in all pipe sewers, to prevent the accumulation of matter within them; from this arises one of the defects of pipe sewers.

The sizes of all house drains and pipe sewers should be such that they should never be more than four-fifths filled with water or sewage, so as to allow of a free circulation of air through them at all times. The air not only facilitates the flowing of the water and promotes ventilation, but it also prevents the accumulation of highly-concentrated gases, and their rising through the drains into the houses.

Mr. Hawkesley has found in the course of his experience that although pipes may be very useful for house drainage, they were of comparatively little use in street drainage, except in those instances where the streets had a great declivity, and there was consequently no danger of the sewers being stopped up. He had generally found it desirable that when sewers were required at a greater depth than 10 feet, to construct them large enough to admit workmen, instead of limiting them to small theoretical dimensions just sufficient to carry off the calculated amount of the water; this obviated the necessity of opening the ground, which was always, and especially when the depth was great, a source of great inconvenience and expense. He has also given it as his opinion that pipe sewers greater than 15 inches in diameter were not so convenient as brick drains, more particularly for forming junctions, nor so economical in point of first cost. He has also said that he had heard of the asserted excellence of those water-tight pipes, when required to be carried through sand beds, but he thought

that drains in that position should, on the contrary, be made so as to allow water to filter into them. He has in some cases employed cast-iron pipes, as also has done Mr. Simpson.

Many errors have arisen from sufficient attention not having been paid to the different circumstances under which water is carried off by sewers.

When water falls on slated roofs and flag surfaces, it makes its escape into the sewers almost immediately, and it has been said on higher authority, that under such circumstances the sewers should be made large enough to carry away a rainfall of 2 inches deep in one hour. In many instances this would be a large quantity of water.

One leading objection against pipe sewers is, at least to a great extent, that the only method of discovering the precise locality of a stoppage is by examining the neighbouring house drains, to enable a guess to be made as to the spot; then it is necessary to open the street to dig down to the pipes and take up a length. If the accretion is within reach of a rod it may be removed; but if not, it is necessary to open other places until the exact place of stoppage is discovered and removed.

There should be a free and full ventilation of all sewers, at all the highest and most convenient points of the town.

Sewers should be below the level of cellars.

As a rule, natural streams should not be part of a system of sewers, and those in low districts should be fully capable of resisting internal pressure.

The sewage of high districts should be intercepted where practicable, so as to preserve a free outlet at all times for this portion of the system.

Large sewers are almost always made egg-shaped, and for the medium size the invert piece is a great additional advantage, particularly in setting out the work, both as regards the levels and the centre line. Small sewers and drains may be circular.

The longest practicable radius should be adopted in laying out curves or lines of large sewers, and there should be as a general rule a greater fall on a curve, especially at a junction with a main sewer.

All sewers and drains should be impervious to water, and should present even and smooth surfaces. The gradient of large sewers in steep ground should be broken; that is, the inclination should be interrupted, or the invert should be made of such material as will resist the tendency to rapid wearing away.

Wherever practicable the outlet or delivery of sewers should be free, and in every case there should be full and free ventilation.

Manure tanks near an outlet may be admissible, care being

taken that such outlet or delivery of the sewage refuse is not blocked or impeded, and that there is no in-draught or back-draught through the sewers.

The real purpose of town sewers is the instant removal from the vicinity of dwelling houses, and from the sites of towns and villages, of all refuse liable to decomposition, and which is capable of being carried away by a current of water. The perfection of the system of the sewage of a town will be in proportion to extent to which this is accomplished.

The formula supplied by Mr. Hawkesley himself for calculating the flow through pipes and sewers is as follows:—

$$V = \cdot 77\sqrt{\frac{HD}{L + 2\frac{1}{4}D}};$$

where V is the velocity in *yards* per *second;* H, the head, and D, the diameter, both in *inches,* and L, the length of pipe in *yards.*

The following table will be found useful and safe for purposes of approximation.

TABLE,

Showing the Discharge in Gallons for 24 hours, of Pipes or Aqueducts of various diameters, and having various Slopes or Falls per Mile.

CALCULATED FROM THE FORMULA OF DU BUAT.

Diameter of Pipe. Feet.	Fall of 20 feet per Mile, 1 in 264. Gallons.	Fall of 16 feet per Mile, 1 in 330. Gallons.	Fall of 14 feet per Mile, 1 in 377. Gallons.	Diameter of Pipe. Feet.
0·25	37,779	33,444	30,958	0·25
0·50	221,860	196,280	181,690	0·50
0·75	621,720	549,860	509,170	0·75
1	1,289,400	1,140,600	1,056,400	1
1¼	2,265,200	2,003,500	1,855,400	1¼
1½	3,590,000	3,175,200	2,940,100	1½
2	7,417,400	6,563,300	6,076,100	2
2½	13,020,000	11,514,000	10.662,000	2½
3	20,602,000	18,223,000	16,872,000	3
3⅓	26,916,000	23,808,000	22,042,000	3⅓
3½	30,419,000	26,907,000	24,917,000	3½
3⅔	34,138,000	30,199,000	27,963,000	3⅔
4	42,492,000	37,580,000	34,799,000	4
4⅓	58,453,000	50,514,000	46,773,000	4⅓
5	74,460,000	65,865,000	60,980,000	5
6	107,200,000	94,820,000	87,802,000	6
8	305,440,000	216,270,000	198,180,000	8
10	421,540,000	372,860,000	345,270,000	10

TABLE,

Showing the Discharge in Gallons per 24 hours, of Pipes or Aqueducts of various diameters, and having various Slopes or Falls per Mile.

CALCULATED FROM THE FORMULA OF DU BUAT.

Diameter of Pipe. Feet.	Fall of 12 feet per Mile, 1 in 440. Gallons.	Fall of 10 feet per Mile, 1 in 528. Gallons.	Fall of 9 feet per Mile, 1 in 587. Gallons.	Diameter of Pipe. Feet.
0·25	28,367	26,187	24,111	0·25
0·50	166,690	150,300	141,530	0·50
0·75	466,830	421,150	396,400	0·75
1	968,420	873,700	822,940	1
1¼	1,701,500	1,532,900	1,445,200	1¼
1½	2,695,600	2,431,100	2,291,200	1½
2	5,570,400	5,023,900	4,734,700	2
2½	9,951,000	8,817,500	8,307,200	2½
3	15,507,000	13,987,000	13,146,000	3
3½	19,744,000	18,233,000	17,173,000	3½
3½	22,840,000	20,654,000	19,427,000	3½
3¾	25,637,000	23,130,000	21,783,000	3¾
4	31,910,000	28,777,000	27,112,000	4
4½	42,885,000	38,681,000	36,436,000	4½
5	55,885,000	50,429,000	47,512,000	5
6	80,360,000	72,611,000	68,411,000	6
8	181,710,000	164,150,000	154,390,000	8
10	318,780,000	288,150,000	270,860,000	10

Diameter of Pipe. Feet.	Fall of 8 feet per Mile, 1 in 660. Gallons.	Fall of 7 feet per Mile, 1 in 754. Gallons.	Fall of 6 feet per Mile, 1 in 880. Gallons.	Diameter of Pipe. Feet.
0·25	22,557	20,938	19,220	0·25
0·50	132,540	123,030	112,780	0·50
0·75	371,420	347,390	315,970	0·75
1	770,510	680,010	655,480	1
1¼	1,322,500	1,255,500	1,151,100	1¼
1½	2,143,800	1,989,600	1,825,000	1½
2	4,131,900	4,112,200	3,770,500	2
2½	7,775,900	7,215,600	6,615,700	2½
3	12,305,000	11,418,000	10,470,000	3
3½	16,076,000	14,927,000	13,679,000	3½
3½	18,168,000	16,863,000	15,505,000	3½
3¾	20,389,000	18,922,000	17,353,000	3¾
4	25,380,000	23,516,000	21,653,000	4
4½	34,116,000	31,658,000	29,029,000	4½
5	44,478,000	41,274,000	37,849,000	5
6	64,042,000	59,429,000	56,019,000	6
8	144,570,000	133,800,000	122,980,000	8
10	253,520,000	235,300,000	215,710,000	10

TABLE—*continued.*

Showing the Discharge in Gallons per 24 hours, of Pipes or Aqueducts of various diameters, and having various Slopes or Falls per Mile.

CALCULATED FROM THE FORMULA OF DU BUAT.

Diameter of Pipe. Feet.	Fall of 5 feet per Mile, 1 in 1056. Gallons.	Fall of 4 feet per Mile, 1 in 1320. Gallons.	Fall of 3 feet per Mile, 1 in 1760. Gallons.	Diameter of Pipe. Feet.
0·25	17,422	15,783	13,166	0·25
0·50	102,420	89,946	77,370	0·50
0·75	286,470	251,980	216,780	0·75
1	593,750	522,280	449,100	1
1¼	1,043,400	917,810	789,110	1¼
1½	1,655,600	1,455,500	1,251,200	1½
2	3,417,000	3,005,900	2,567,500	2
2½	5,999,700	5,275,600	4,698,700	2½
3	9,492,100	8,351,000	7,373,000	3
3½	12,398,000	11,393,000	9,356,600	3½
3½	14,013,000	12,312,000	10,879,000	3½
3¾	15,727,000	13,840,000	11,900,000	3¾
4	19,616,000	17,302,000	14,811,000	4
4½	26,307,000	23,147,000	19,910,000	4½
5	34,286,000	30,174,000	25,955,000	5
6	49,412,000	43,445,000	37,372,000	6
8	111,470,000	98,066,000	84,328,000	8
10	195,500,000	172,040,000	147,590,000	10

With regard to the quantity of water delivered by large pipes, Mr. Bateman has said that at Glasgow the four-feet pipes which were calculated to deliver 20 million gallons per twenty-four hours, with five feet fall per mile, have delivered 26 million gallons with a fall of 3½ feet per mile. He could only account for this by two causes: either it was that the surface, which was like glass, was so smooth that it rendered the conditions different from those which existed when the experiments were made by the various experimentalists on hydraulic velocity, from whose results our ordinary calculations are deduced; or that the size of the pipes was so much larger than those experimented upon that the formulas do not apply. "The fact, however, is, that in the condition in which the Glasgow pipes were when the water was first introduced into them they certainly delivered something like 40 per cent. or 50 per cent. more water than the calculated results, taking the formula which we are accustomed to use." It seems doubtful if the coefficient is high enough for well-laid and asphalted cast-iron pipes.

Practically, no undulations, except abrupt curves, will interfere with the delivery. In designing a system of pipes or sewers it is well to remember that the larger the diameter the more economical will be the system, provided of course that the diameters are useful for discharge. It is to be considered in the case of the Glasgow pipes above referred to that they were asphalted, which Mr. Bateman considered costs about 5*s*. per ton additional on the cost of the pipe. The pipes at Manchester were asphalted inside and out on the plan of Dr. Angus Smith, which, when the work is well done, answers extremely well. Pipes examined after ten or twelve years use appeared as fresh as when first done.

The following is from information supplied by Mr. Bateman:—

Cost of Brick Culverts as compared with Cost of Cast-iron Pipes.

Diameter 2 feet, thickness of brickwork 4½ inches.
·311 of a cubic yard in a yard forward.
547·5 cubic yards per mile.
3090 cubic yards of excavation per mile.

Diameter 3 feet, thickness of brickwork 9 inches.
·981 of a cubic yard in a yard forward.
1726·5 cubic yards per mile.
6600 cubic yards of excavation per mile.

Diameter 4 feet, thickness of brickwork 9 inches.
1·246 cubic yards in a yard forward.
2193 cubic yards per mile.
9142 cubic yards of excavation per mile.

Diameter 5 feet, thickness of brickwork, sides 1′, 2″, top and bottom 9″.
2·113 cubic yards in a yard forward.
3719 cubic yards per mile.
13470 cubic yards of excavation per mile.

In the form adopted for culverts, the sectional area is larger than that of the corresponding cylinder. For pure water it is the best form, because there being no matter in suspension to carry along with the water, there is not required a greater velocity and bottom; therefore for sewers the egg-shape has the advantage, on account of the sewage matter to be conveyed away with the water.

In Manchester all the covered conduits for conveying the water are either of stone or brick to the point where they begin to distribute. For the Bradford waterworks the water is conveyed for a considerable distance by a stone tunnel from the valley of the Wharfe. For the Halifax waterworks the water is conveyed by stone or brick culverts to the point of distribution.

For Glasgow, except where they cross three deep gorges, between Loch Katrine and the Mugduck reservoir, a distance of 27 miles, the whole of the water is conveyed by tunnels or covered masonry culverts.

Cost per Mile for Brickwork Culverts and Cast-iron Pipes.

Diameter of Sewer.	Brick-work at 15s. per cubic yard.	Brick-work at 20s. per cubic yard.	Brick-work at 25s. per cubic yard.	Excavation at 1/6 per cubic yard.	Total cost at 15s. per cubic yard.	Total cost at 20s. per cubic yard.	Total cost at 25s. per cubic yard.	Total cost of Cast Iron Pipe at £5 per ton.	Total cost of Cast Iron Pipe at £6 per ton.
Feet.	£	£	£	£	£	£	£	£	£
2	410	547	684	232	642	779	916	3092	3552
3	1295	1726	2157	495	1790	2221	2652	5676	6583
4	1645	2192	2741	685	2330	2878	3426	9267	10,769
5	2789	3719	4649	1010	3799	4729	5659	13,885	16,134

In the following table of the cost of cast-iron pipes per mile, the surface of the pipe is supposed to be laid at 3 feet below the surface of the ground; but there is no allowance for the transport of the pipes; the cutting of the trenches, and refilling them, the jointing and laying, with the spun-yarn and lead to be used in doing so, are all included for ordinary average work, but not for rock cutting, nor work carried on in towns.

Economy, combined of course with efficiency, is one of the most important of considerations in all engineering works; and it is particularly the case as regards waterworks and sewers. For both, the extravagant cost of piping may often be avoided by adopting the more ordinary kind of aqueduct of brick or stone; or where cutting through rock, there is often no necessity for anything more than cutting the trough, and lining where the rock is tender; in going through sandstone it will require rendering in hydraulic cement.

Clay puddle may be considered objectionable for puddling behind the side walls and over the arches of aqueducts; more particularly in sidelying ground, the water passing down the hill-side, and through the new-made ground, gets behind the clay and melts it. It is better to use concrete for the backing. Clay puddle is very often an important element of hydraulic constructions, but where used inconsiderately it may be a source of great danger.

ESTIMATES.

Cost of Cast Iron Pipes, including Laying and Jointing, per Mile.

Diameter of Pipe in feet.	Working Pressure.	Thickness.	Weight per Lineal Yard.	Weight per Mile.	Cost per Mile at £5 per Ton.	Cost of Laying and Jointing per Mile.	Total Cost per Mile.	Cost per Mile at £6 per Ton.	Cost of Laying and Jointing per Mile.	Total Cost per Mile.
	Feet.	Inch.	Cwt. qrs. lbs.	Tons.	£	£	£	£	£	£
2	100	$\frac{3}{4}$	5 1 3	460	2300	792	3092	2760	792	3552
„	200	$\frac{7}{8}$	6 0 21	544$\frac{1}{4}$	2721	„	3919	3263	„	4057
„	300	1	7 0 12	625$\frac{1}{2}$	3127	„	3919	3753	„	4545
„	400	1$\frac{1}{8}$	8 0 4	707	3535	„	4327	4242	„	5034
3	100	1	10 1 13	906$\frac{1}{2}$	4532	1144	5676	5439	1144	6583
„	200	1$\frac{1}{8}$	11 1 25	1010	5050	„	6194	6060	„	7204
„	300	1$\frac{3}{8}$	13 3 14	1221	6105	„	7249	7326	„	8470
„	400	1$\frac{3}{4}$	17 2 13	1590$\frac{3}{4}$	7953	„	9097	9544	„	10,688
4	100	1$\frac{1}{4}$	18 0 23	1501$\frac{1}{2}$	7507	1760	9267	9009	1760	10,769
„	200	1$\frac{1}{2}$	21 0 24	1888$\frac{1}{2}$	9442	„	11,202	11,331	„	13,090
„	300	1$\frac{3}{4}$	25 0 11	2295$\frac{1}{2}$	11,492	„	13,252	13,791	„	15,551
„	400	2$\frac{1}{8}$	31 0 7	2733$\frac{1}{4}$	13,666	„	15,426	16,400	„	18,160
5	100	1$\frac{1}{2}$	25 2 6	2249	11,245	2640	13,885	13,494	2640	16,134
„	200	2	34 1 12	3023$\frac{1}{2}$	15,117	„	17,757	18,141	„	20,781
„	300	2$\frac{1}{4}$	38 3 0	3410	17,050	„	19,690	20,460	„	23,100
„	400	2$\frac{1}{2}$	43 1 5	3810	19,050	„	21,690	22,860	„	25,500

TABLE

Of the Weights of Cast Iron Pipes.

Diameter of Pipe.	Length of each Pipe.		Thickness of Metal.	Depth of Socket.	Mean Weight of Pipe.			Permitted deviation in weight.	Mean weight of Pipe per Mile.	Proof Pressure, or height of column of Water.	Pressure per Square inch.	Maximum working Pressure.
Inch.	Ft.	In.	Inch.	Inch.	Cwt.	qrs.	lbs.		Tons.	Feet.	lbs.	Feet.
33	12	5	1	5	39	1	25	2 %	868·4	400	173	210
30	12	5	1¼	5	44	0	3	,,	968·6	600	260	300
30	12	5	1	5	35	3	5	,,	807·1	500	217	230
24	12	5	1	5	28	1	23	,,	626·0	600	260	300
20	,,	,,	⅞	4½	16	0	4	,,	451·6	500	217	270
20	,,	,,	¾	,,	13	3	25	2½ %	393·5	450	195	240
18	,,	,,	13/16	,,	13	1	12	,,	376·2	600	260	300
18	,,	,,	¾	,,	12	1	19	,,	349·7	500	217	260
18	,,	,,	11/16	,,	11	1	27	,,	323·6	450	195	230
16	,,	,,	¾	,,	10	3	27	,,	309·5	600	260	300
16	,,	,,	11/16	,,	10	0	18	,,	286·1	500	217	250
16	,,	,,	⅝	,,	9	1	9	,,	262·8	400	173	200
15	,,	,,	11/16	,,	9	2	3	,,	268·8	500	217	270
15	,,	,,	9/16	,,	7	3	25	,,	224·1	400	173	180
14	,,	,,	11/16	,,	8	3	23	,,	252·2	600	260	290
14	,,	,,	⅝	,,	8	0	25	,,	231·6	500	217	250
14	9	4½	9/16	4½	7	2	0	,,	211·2	400	173	200
12	9	4¼	⅝	4¼	6	3	13	3 %	193·8	600	260	290
12	9	4¼	9/16	4¼	6	0	26	,,	175·9	500	217	240
10	9	4	9/16	4	5	0	16	,,	145·6	400	173	300
9	9	4	9/16	4	4	2	24	,,	133·4	600	260	,,
8	9	4	½	4	3	2	23	,,	104·9	500	217	,,
7	9	3½	½	3½	3	1	1	4 %	92·6	600	260	,,
6	9	3½	7/16	3½	2	1	27	,,	70·8	,,	,,	,,
5	9	3½	7/16	3½	1	3	24	,,	55·8	,,	,,	,,
4	9	3	7/16	3	1	1	20	,,	40·8	,,	,,	,,
3	9	3	7/16	3	1	0	10	,,	31·1	,,	,,	,,
2	9	3	7/16	3	0	2	4	,,	15·3	,,	,,	,,

Specification of Cast Iron Piping for Waterworks.

The whole of the pipes shall be subject to hydraulic pressure according to annexed schedule (see last page), and each pipe whilst under pressure must be rapped from end to end with a hand hammer, so as to discover any porous, blown, or sandy places in the metal; the weight of the hammer to vary from 4lbs. to 7 lbs., according to the size of the pipe and thickness of metal in the casting.

The whole of the pipes to be of the best grey metal, remelted from the cupola, and to be perfectly free from flaws and defects of every kind; all the pipes to be cast vertically in dry sand moulds, and to be of uniform bore, and uniform thickness of metal throughout, and without any belts.

All pipes above 12 inches in diameter to have wide sockets for lead joints; pipes of 12 inches and smaller diameter to have principally turned and bored joints, from 5 to 20 per cent. of each size, according to circumstances, having wide sockets.

All pipes with wide sockets above 4 inches in diameter to have three-eighths of an inch for the joint; the pipes of 4, 3, and 2 inches in diameter to have one-fourth of an inch for the joint.

All pipes of 18 inches diameter and upwards to be cast with the socket downwards; those below that size may be cast with the socket upwards.

All pipes to be carefully coated inside and out with coal pitch and oil, according to Dr. Angus Smith's patent process. The coating to be applied at a proper heat, and in a proper manner, before any rust sets in. The operation is to be performed under the inspection of an appointed officer.

In Ireland Mr. Neville has constructed a large quantity of main sewers from 18 inches to 2 feet and 2 feet 6 inches wide, and 4 feet 6 inches high; the side walls built with rubble masonry; 9 inch segment inverts, laid with 1½ inch courses in cement; the top sometimes flagged, when flags of sufficient length could be procured, and sometimes arched with rough rubble arches. The invert was laid on well-bedded and well-rammed rubble to prevent subsidence, and preserve the bottom inclination uniform. The cost at an average depth of about 9 feet was about 9*s*. per foot lineal; the side walls being about 18 inches thick. Upright side walls, where rubble is cheap, have many advantages in giving a considerable increase of capacity for a small outlay.

The following is from the Summary of Public Works for Preston in 1859:—

Yards.			£	s.	d.
60	brick sewers,	2 ft. 6 in. in diameter, @ 7s. .	21	0	0
538	do.	3 ft. by 2 ft., @ 17s. 6d. . . .	470	14	3
294	do.	3 ft. 6 in. by 2 ft. 4 in., @ 28s. 8d.	412	12	11
372	do.	3 ft. 9. in. by 2 ft. 6 in., @ 28s.	520	16	0
250	do.	4 ft. 3 in. by 2 ft. 10 in., @ 41s. 9d.	521	16	8
56	do.	4 ft. 6 in. by 3 ft., @ 75s. 7d. .	211	13	4
66	do.	4 ft. 6 in. diameter, @ 40s. 9d. .	134	9	6
1636			2293	2	8
	42 cast iron sewer,	2 ft. diameter, @ 36s. . .	75	12	0
	22 earthenware pipe sewer,	6 in. diameter, @ 4s. .	4	8	0
1129	do.	do. 9 in. diameter, @ 7s. 5d.	418	13	5
565	do.	do. 12 in. diameter, @ 8s. 9d.	247	2	9
88	do.	do. 15 in. diameter, @ 11s. 3d.	49	10	0
98	do.	do. 18 in. diameter, @ 13s. .	63	14	0
145	do.	do. 21 in. diameter, @ 18s. 6d.	134	2	6
2089			917	10	8

Cost of Sewers in Newport, Wales.

Total Lengths. Feet.	Average Depths. Feet. Inches.	Sizes of Sewers. Ft. In. Ft. In.	Thickness. Inches.	Cost Foot Lineal. s. d.
1322	15 6	4 6 by 3 6	9	11 8
2217	13 0	4 6 „ 3 0	9	10 1½
6110	12 0	3 0 „ 2 2	9	7 7¼
12,354	11 8	3 0 „ 2 2	6	5 3¾
1953	9 3	2 6 „ 1 10	6	4 7
9663	10 0	2 6 „ 1 10	4½	3 8¼
690	10 2	2 3 „ 1 9	4½	3 5¼
3264	8 6	1 2 diameter	4½	2 4¾

Estimate for Sewers at Brighton.

			£	s.	d.
4850	lineal yards brick sewer . . .	6 feet diameter, @ 70s.	16,975	0	0
350	„ „	4 ft. 6 in. „ @ 50s.	875	0	0
3990	„ „	4 ft. 6 in. by 3 ft. @ 48s.	9600	0	0
1890	„ „	3 ft. 9 in. by 2 ft. 6 in. @ 42s.	3969	0	0
2820	„ „	3 ft. by 2 ft. @ 36s.	5076	0	0
8580	„ „	2 ft. 3 in. by 1 ft. 6 in @ 18s.	7722	0	0
22,480					

			£	s.	d.
9466	lineal yds. earthenware pipe sewer	15in. diameter, @13s. 6d.	6389	11	0
44,430	„ „	12 in. „ @10s.	22,215	0	0
53,896					
750	lineal yards, cast iron pipes . .	3 ft. diameter, @140s.	5250	0	0
1260	„ „	1 ft. 6 in. „ @60s.	3780	0	0
2010					

Length of sewers, 44 miles 956 yards.

600 manholes and ventilating shafts, @ £20	12,000	0	0
600 lampholes, @ 80s.	2400	0	0
300 gullies, @ 70s.	10,500	0	0
Add for outlets, overflows, and extras	5000	0	0
„ contingencies, including repairs for existing sewers, 10 per cent.	11,178	0	0
	£122,930	0	0

Earthenware Pipes—Laying only.

	s.	d.			
12 inches diameter . . .	0	8	per foot lineal	. . 5	feet deep.
15 „ „ . . .	0	9	„ „	. . 5	„
18 „ „ . . .	0	11	„ „	. . 5	„
Relaying pavement . . .	0	6	„ „		
Ditto Macadamised roads	0	4	„ „		
Ditto pitching . . .	0	2	„ „		

Reinstating Roads.

Gravel roads . . .	1s. 3d. per super. yard.
Macadamised . . .	1s. 9d. „ „
Pitch Pavement . . .	2s. 0d. „ „

Memoranda for Specifications.

All buildings and out-buildings to be properly spouted, and the water to be conveyed into the sewers as directed and approved of by the surveyor. Rain-water from the roofs not to be conveyed to the basements.

Rain or other water not to be conveyed from the rear of premises to the front under basement floors, without consent of the surveyor.

No private drain must be put in with a less fall than one in ——, without the sanction of the surveyor. Cast iron pipes may be used for basement drains in some instances.

All stench traps to be similar to the pattern furnished by the surveyor, or of such pattern as shall be approved by him, and they shall be properly fixed to his satisfaction.

No watercloset should be allowed on basement floors, but where it cannot be otherwise arranged the soil pipe should have a stench trap or other contrivance such as the surveyor may consider necessary to prevent any influx of sewage water.

All waterclosets should be of a description approved of by the surveyor, and should be fixed to his satisfaction.

All sewers of waterclosets should not be less than six inches internal diameter, and all sewers to yards, stables, kitchens, and sculleries should not be less than four inches internal diameter; this is a size commonly allowed, but we should prefer a larger size.

All down spouts should be connected, when it may be proper to make such connexion, to the satisfaction of the surveyor; and where they are not connected with the sewer they are to be properly connected with the channel.

All ash pits and sites for dunghills shall be raised to the level of the adjoining ground, and they shall be paved and drained as the surveyor may direct.

No pipes, waterclosets, stench traps, gullies, kitchen sinks, bends, junctions, or tapering pipes to be used until approved of by surveyor.

In every case the whole of the fall to be made available from the junction with the main sewer to the end of the private drain; that is to say, only one inclination to be used from the junction with the public sewer to the end of the private drain; and all branches from the private drain to sinks, waterclosets, &c., to have one inclination from the junction of such drain. None of the above instructions to be departed from without the express sanction of the surveyor.

CHAPTER V.

SEWAGE AND IRRIGATION.

How we are to dispose of the sewage of large towns has for a long time past become an important social and engineering question. Each year the subject becomes more momentous. In many cases, the question of the town's water supply waits upon the question of the disposal of sewage.

This was the case as regards a scheme proposed this year (1867) by the East London Waterworks Company. It was part of that scheme that the company should construct certain intercepting sewers, to aid in the purification of the River Lea, for the purpose of enabling them to supply purer water; the Metropolitan Board of Works objected that the intercepting sewer was not extensive enough for the purpose proposed, and the pressure of circumstances compelled the company to withdraw the application for power to make those sewers, because it would be conflicting with some other powers soon to be created, and the company could not make their drainage system more comprehensive. The company's engineer admitted that, except so far as a little above Enfield Mill was concerned, there was nothing to prevent the sewage of all the towns above that part of the Lea from coming into the Lea.

It was essential to the company's proposed scheme that the intercepting sewer should be carried up as far as the Town of Waltham Abbey on one side, and up to the neighbourhood of Waltham Cross on the other side. The engineer to the Metropolitan Board of Works reported upon the portion of the bill which proposed to continue the intercepting sewer, which the company had already constructed, to a higher point, considering with reference to those works, that they did not appear such as could purify the water of the Lea, and that to be effective they should be of a more extensive character. The result was that the proposed works were struck out of the company's proposed bill. The Metropolitan Board of Works thought that the East London Waterworks Company should make a very considerable contribution to any plan for the purification of the River Lea, and from this the company totally differed.

In London, at present, the excretory matter of about 3 millions

of population is carried daily through the sewers; although they may be too well designed and too well built to be cesspools of solid deposits, we must remember that there is a large amount of grease and kitchen refuse which find their way daily into the sewers, and we shall not be very much beyond the mark if we consider that three pounds per individual finds its way daily into these channels of conveyance; altogether we may consider that about 9 millions of pounds is thus ejected per day.

Immediately that this reaches the running sewage, it begins to decompose, or becomes putrid; it would be very difficult under such circumstances to imagine that the sewers can be very "sweet," to use the technical phrase as regards sewers; indeed, open manholes anywhere in London will convince us of the contrary, and the best chemical evidence asserts that these smells are warnings of the presence of dangerous gases. The most that can be said on the subject is, that we did the best we could for the times.

We are free, however, to express the opinion that we believe the watercloset system, as at present existing, to be doomed; and we think that it is merely a question of time. All our hydraulic engineers have admitted that there is a common practice of propping up the handles of waterclosets to allow the water to run to waste, or in other words to cleanse the pipes as people think; and they all tell us very plainly that this merely allows of bad smells making their way into the houses, and no one can reasonably refute their evidence; this only goes, however, to show that the sewers cannot be very "sweet." At the commencement of the first volume of "Engineering" there were some very powerful and equally sensible articles on the subject of London Sewers.

In Manchester, public opinion is quite different to what it is in London on the subject of waterclosets, and we do not think we shall depreciate the people of the metropolis by saying that we consider that the men of Manchester have as much forethought as we have.

Now the public opinion of Manchester argues in this way. The mischievous consequences resulting from the encouragement if not the obligation, to introduce waterclosets into houses, small as well as large, can hardly be overrated. Why a course which will lead to similar results in every other district to what they are in London, should be so recklessly insisted upon, it is difficult to imagine. We find complaints arising, on all sides, of the present foul and pestilential condition of formerly pure trout streams, by reason of the house drainage and town sewage which is turned into them—evils resulting entirely from the introduction of waterclosets into all houses. How these consequences are to be

avoided when waterclosets are generally adopted, our theorizing sanitary reformers do not suggest. Nor have they ventured to estimate the expense which must be incurred in any attempt to obviate the evils complained of. Villages spring up in comparatively rural districts; waterclosets are adopted as a matter of course, without considering what may be the result, or who is ultimately to be poisoned; and the drainage is turned into the nearest stream.

It may be observed that all attempts to induce the gentlemen who opposed the proposition of the Manchester Corporation, in 1858, to obtain power from Parliament to discourage the introduction of waterclosets into small houses, to give any estimate of the additional expense which the carrying out of their favourite scheme would involve, were unsuccessful.

In the city of Manchester there are upwards of 66,000 houses, of which more than 51,000 are of the rent of 10*l.* and under. It may be said that in effect, there are no waterclosets in Manchester, certainly not in the smaller class of houses. The town sewage finds its way into the rivers, and the filthiness cannot be denied; but it arises more from the drainage of dye works and manufactories than from the sewage of the city. What the state of the rivers would have been, if, as in many other places, the authorities of Manchester had been subject to the influence of the watercloset mania, as it has been termed, it is difficult to imagine.

The great difficulties to be overcome in getting rid of the immense quantity of refuse from a large town would not be experienced in smaller ones. The difficulty arises from the mass of matter, and from the distance to which we must go to find customers. The farmers who come with agricultural produce to market would be able to take away only a small quantity. Night soil must be removed, and that speedily, and to accomplish this the corporation of Manchester has been compelled to make their arrangements for sending it by railway into the agricultural districts of Yorkshire, Nottinghamshire, and Lincolnshire. If the watercloset system were generally carried out, the inhabitants of Manchester would be subjected to much greater additional expenses, and to an enormously increased nuisance, whilst in all probability the corporation would be compelled at any rate to expend in the removal of the ashes, which alone would still remain, and be altogether unsaleable, a larger sum than is now found sufficient to cleanse all ash-pits, and keep the city in a satisfactory sanitary condition. They remove annually about 100,000 tons of night soil and ashes from upwards of 36,000 ash-pits. It is sent by railway into Yorkshire, Nottinghamshire, and Lincolnshire. The price charged, exclusive of cartage, is

about 1*s.* 6*d.* per ton, and the carriage added. Much depends upon the distance it is conveyed, and the cost fluctuates between 3*s.* 6*d.* and 7*s.* 6*d.* per ton. The whole expense incurred during the past year amounted to 16,130*l.*, which was reduced by the sale of manure to 6,644*l.* In a small town, especially one situated in an agricultural district, the system adopted in Manchester may be made, we believe, not only to pay all expenses, but to leave an actual profit to the authorities. If every house, and especially every small house, had a watercloset by which the soil would be destroyed for agricultural purposes the city would be involved in endless trouble and expense; but if all had convenient and dry ash-pits, not cesspools, the sanitary condition of the city would be far better than if all had waterclosets, with all their attendant difficulties and inconveniences. The streams would be little, if at all, interfered with by the drainage; the contents of the ash pits would be most valuable for agricultural purposes,—would in many cases be paid for and removed without expense by the farmers, and when not taken away by the farmers, they might be removed by the authorities at little, if any, expense, when credit is taken for the amount which would be realized by the sale. This plan seems to be consistent with common sense. At any rate, until our great sanitary luminaries have been able to enlighten the public as to the mode in which the enormous evils resulting from the watercloset system can, at any bearable cost, if at all, be avoided, it is deserving of support and encouragement.

It appears that there is a somewhat similar system adopted in Glasgow. Within the last few years they have been getting rid systematically of the privies, and have been introducing other means of getting rid of excrementory matter. It has been done in such a way that not a particle of it finds its way into the sewers. There is no water used. The whole collections are carried out to the extent at least of 80,000 inhabitants. The system is to a large extent fixed receivers, not removable. The receivers themselves are not handled, nor do they use any deodorizers; the soil is just collected and it is removed every morning. At one time there was a large quantity of dry garbage collected, and people could not be found to take it away for nothing; but a system was introduced of collecting ordure to mix with it, and the whole was carried away and applied to agricultural purposes. The contractor now takes away the dry garbage, and mixes it with the ordure of the closets, and sends it away to distant counties, it is believed at a considerable profit.

The whole of this, of course, is diametrically opposed to our preconceived ideas of sewers and sewage, although it is only

within a few years that the watercloset system, and that of sewers as at present existing, have been adopted. So much, however, has been said about it that to some extent we consider ourselves bound to abide by it. Possibly we may be able to defend it for a time.

Nevertheless, it must certainly be admitted that the opposition to the present watercloset system and to that of sewers has got a firm hold on public opinion, and it would certainly be strange if our profession is behind the time instead of being before it.

Many of us remember the first era of railways, of gas, of steam navigation, and of electric cables. Is it not possible that the same revulsion may take place as regards sewerage, and that that which is now considered impossible, and unprofitable, may in a short time become easy, and also a commercial success? On this subject a friend of ours has just reminded us of a fact which is by no means beside the subject we have in hand; it is not very many years since dust contractors were paid for carting away ashes, &c.; the matter is now reversed, and they in their turn pay for the privilege of doing this, and make a profit. May it not soon be the same with regard to the removal of ordure? Manchester management would appear to say that it will be so at some time.

The name of Dr. Thomas Hawksley has lately become very familiar in connexion with the removal of ordure. His system, however, is exceedingly similar to that proposed some few years since by Mr. Jasper W. Rogers, C.E.* This gentleman advocated the use of peat charcoal as a deodorizer instead of earth, and it has been well proved that this charcoal is a powerful fertilizer as well as a deodorizer. The pamphlet we have above referred to will be found to repay perusal, both with regard to the proposed system of sewerage, as well as to the details therein explained. Mr. Rogers called public attention to his proposals as far back as 1849—long before Dr. Hawksley's name became connected with the subject. In his preface Mr. Rogers observes:—

"The recent publications of Drs. Copland and Hawksley on the subject of removing and deodorizing the excretory matter of houses, also do me the honour of coinciding almost entirely in my views. It will be seen by the Appendix how closely we agree—mine put forth in 1849, theirs in 1857. If the propositions and views of those several gentlemen have arisen without a knowledge of mine, I shall be well pleased, as they offer evidence in favour of the correctness of what I have advanced so long since. If they have adopted my ideas I shall be equally gratified, because

* "Facts and Fallacies of the Sewage System of London and other large towns." Atchley and Co., 106, Great Russell Street, Bedford Square.

I have the weight of their judgment in favour of mine. But it is impossible to avoid the reflection that had the general scientific mind of London been then directed towards investigation, not opposition, better results would in all human probability have been attained. Such a course, even now, would, I believe, be most desirable; and in simple words I challenge discussion and investigation of a subject which affects the interests, well-being, and happiness of every resident of London and all large towns."

At page v. of the Appendix, Mr. Roger remarks, "That carbon, hydrogen, nitrogen, oxygen, gluten, phosphoric acid, silicate of potash, chloride of sodium, carbonate of lime, sulphate of lime, and ammonia, are interwoven, it may be said, into every grain of charcoal, when properly amalgamated with night soil. That carbon, the staff of vegetation, gives to the plant carbonic acid, and all the other essentials for vegetable luxuriance are held in the most powerful combination; whilst, according as the charcoal yields the gases it has absorbed, it becomes ready to receive a further supply, and every shower of rain that falls imparts to the charcoal additional quantities of ammonia and salt from the atmosphere. Thus each grain of charcoal becomes a reservoir, not only of moisture, but of manure, as long as it remains in the land."

On this subject we must now refer to the opinion of Dr. Angus Smith, and of Dr. Frankland.

Dr. Angus Smith states that if you take land which is perfectly free from any sewage, you find that there are emanations arising from it; and if water be allowed to lie upon this land very long, the organic matter in the water putrefies, and there is an escape of gases; according to the time during which the water lies, and according to the temperature of the air, noxious gases will rise. That those should occur in greater quantities when a greater amount of organic matter is thrown upon the land, is of course a natural consequence; it is an absolute necessity. "This amount I have measured in various places, and distinctly know that it arises from the condition of the ground, the amount of moisture and organic matter upon it." It is quite true that the soil is a great disinfectant; that it absorbs impure matter with intense rapidity; but of course there is a considerable amount left upon the surface when the land is manured with liquid manure, and there is always a certain amount left upon the blades of grass, and upon the vegetation; that of course must have its effect. There is an increased evaporating surface given, which also increases the effect; of course at the same time there is an escape of the useful products of the manure; but the action of the air upon the organic matter is also excessively rapid; the organic

matter in the sewage water comes to be oxidized, forming carbonic acid and other gases immediately on its escape from the town, or much sooner, and the decay of the manurial properties is of course also excessively rapid; the sewage water therefore is a substance which will not preserve long; "it must be used, I believe, immediately; this action of the air upon the organic matter has often been supposed, but I have lately been making some experiments upon it, and find that it can be traced very readily; even in peaty water the organic matter is very rapidly oxidized; it may have, to-day, when you examine it, five or six cubic inches of carbonic acid, and to-morrow it may have 10 or 20 inches of carbonic acid; and still more does this occur with the water of the sewers; but in order to trace this putrefaction I took blood, as being a liquid of which we know pretty well the chemical composition, and as containing albumen, which may be said to be a type of those putrescible organic substances which can be found in the soil or in manure. I have found that whenever the temperature rose to about 54°, the oxidation was intensely rapid, and there was more than oxidation; there was an evolution of carbonic acid gas from the destruction of the substances in solution in the blood itself. These gases came out with immense rapidity. The most abundant was carbonic acid, which rose from 82 per cent. up to 95; the sulphuretted hydrogen was 1·93 per cent.; the remaining 3 per cent. consisted of carbonic oxide, 4·8 per cent., carburetted hydrogen 2½ per cent., hydrogen 6·2 per cent., and nitrogen 86·5 per cent. These are the gases that come off; they come off from all sewage water, and they come off in similar proportions generally; and these are the gases which come into our houses from the sewers, and which are given out from the land also, when land is in a state of too great moisture and heat, and when it is in an unwholesome condition. I conceive that it is an important thing to prevent the destruction of this organic matter, for two reasons; first, for the sake of health; and next, for the sake of preventing its loss."

Dr. Angus Smith examined the gases from putrefying matter, in order to ascertain what it was that escaped, and he found that the whole substance in solution was undergoing a rapid decomposition; the best way to arrest this is, in his opinion, the use of a disinfecting agent. That which he has found the most efficient and easy is the use of carbolic acid or creosote; that is a substance which rapidly prevents the decomposition of organic matters. Its constituents are—carbon, 12; hydrogen, 6; and oxygen, 2. It is sometimes called phenic acid. When it is put into sewage water the carbonic acid and sulphuretted hydrogen cease to escape; it prevents the action of oxidation, and of breaking

up or putrefaction. He considers that about two ounces of phenic acid is sufficient for 300 persons per day, and thinks that the cost would amount to about 12,600*l.* per annum for a population of 2½ millions.

Lime throws down all the flocculent matter which is floating, and also all the phosphoric acid, but it cannot take down all the salts of ammonia, potash or soda; indeed it rather favours the escape of ammonia.

Phenic acid is used with the sewage of Carlisle, where it is applied for irrigating the land in the neighbourhood, and it has also been used at Croydon.

The power of charcoal as a deodorizer is fully admitted, but it has the power of absorbing oxygen to a greater extent, and it compels oxidation more rapidly than the ordinary atmosphere.

The question now is, whether charcoal, being a powerful fertilizer as well as a good deodorizer, might not be used in combination with phenic acid and sewage to produce a valuable and permanent manure.

A comparison of the chemist's opinions with many of those of Mr. Rogers, the engineer, will be found very interesting, and both alike well worthy of perusal, as regards the fatal emanations that may arise from sewers.

The following few observations we deduce from the opinions given by Dr. Frankland:—If the coagulated albumen is finally conveyed to the soil the only loss likely to arise is from the precipitation of sediment somewhere in the passage of the liquid through the sewers; if the albumen is coagulated it will be precipitated, and by this process it will be left immediately available for the crops; it will be more likely to lie for a certain time dormant in the soil after the application, but it will be eventually utilized.

Up to the present time all our eminent authorities appear to have considered the question in one light only; simply the getting rid of the sewage, and every other consideration has been made subservient to this.

Notwithstanding all that has been stated by the eminent Dr. Letheby, there is a very decided opinion that water which has once become polluted by sewage matter cannot be purified by any known mechanical or chemical means; neither filtration, deodorization, precipitation, nor a prolonged length of current, will so purify the water as to render it fit for drinking purposes.

Whether the sewage be sewage proper, untreated sewage, or sewage in any other form, the evil may be very considerably diminished by throwing it into a large body of running water, that is, into a river of considerable size; this we believe is the

most that can be said upon the subject. Therefore, to get rid of the sewage, we poisoned the waters of our rivers, and then set about filtering them, and to a considerable extent we do so still.

The Royal Commissioners for 1857 considered, *under all circumstances*, that precipitation was the plan for dealing with the London sewage; that the solid matters should be there separated and precipitated, and the liquid treated with some deodorizing agent before discharge. But this report had been made when it had already been decided that the sewage of our 3 millions should be ejected into the Thames. The proposal, under the circumstances, was somewhat of a compulsory nature, and the most likely under conditions to be available with the means and the disposition of the London public as then existing. It was not the scheme which they should have preferred by any means, but it was the only one which was possible at the moment. It was then considered impossible that the London public would vote five or ten millions of money for dealing with the sewage on a large scale.

We wonder how much has actually and really been spent, and to what purpose, eventually; and not only this, but how much more will have to be spent, and how much has been simply wasted.

As far as we have got with the subject at present, the universal cure recommended "under authority" is that if the sewage of towns is no longer to flow into rivers, the only alternative which remains is to dispose of it upon the lands.

"From time immemorial until within the last 30 years it has been the custom to utilize all the night soil and other refuse on the land. Great obstructions used to be thrown in the way of making house drains which should empty themselves into the street sewers; the use of the latter was confined to the conveyance of the surface waters of the town. There was a service of scavengers, whose duty it was to remove excrementitious matter in their carts. And it was the office of the mayors of towns to take care that rivers, streams, and ponds were kept free from all noxious or filthy substances. But when the modern waterclosets came into vogue, and the practice was introduced of flushing house drains into the sewers, then the diluted night soil first began to find its way into rivers. Yet the removal of house refuse to the land would now be much cheaper and easier than it was formerly, because carriage by suspension in a liquid is the cheapest mode of transport."

It might perhaps have been added that it was the cheapest and easiest mode of getting rid of the sewage in one sense, but the most expensive ultimately; the cheapest and easiest mode of

getting rid of a troublesome subject for a time, but which ultimately must return with tenfold energy and virulence, and the cheapest and easiest mode of disseminating in every direction all the poisons which sewage is capable of conveying.

There can be no doubt whatever that sewage irrigation may often be successfully applied, that is, beneficially in a sanitary point of view, which after all is the most important and economical for all communities, and also under commercial considerations.

Neither can there be any doubt that the conveyance and distribution of sewage may also be a great nuisance. There is a constant evaporation not only from the surface of water, but also of impure matter even should no water arise. An account has been given of the gases that do rise, which they do instantly and rapidly, and if the sewage matter is thrown over the ground the gases must continue to rise.

With regard to the methods which have been proposed of one strong dressing, or several weak applications of sewage, Dr. Angus Smith considers that in either extreme there would be very great loss; that the loss by strong manure is very great, as also that from very weak sewage.

"From 50 grains to 700 of ammonia might be got from 100 gallons of sewage water. If you take any amount of water from a drain you will get in one gallon ·80 perhaps, or ·01 in a gallon. In 100 gallons you will get perhaps a grain of ammonia; water rendered impure by sewage from towns, may be found to have as little as two grains in 100 gallons; these two grains in 100 gallons were sufficient in a case which I recently examined to cause this water to be exceedingly impure, and the people who drank it were attacked by an epidemic which caused a very great calamity in the town this year. This very small quantity therefore of ammonia, I believe, indicates a large amount of impurity in that water, and the result proves that even that amount may be very disastrous when drunk; any amount beyond that I consider may be called sewage water. Suppose we come to 100 grains per 100 gallons, and so on, it may be called somewhat like sewage water until we come up to about 300, when it is very fair sewage water."

It is difficult to say what is safe, and what is not safe. There is a canal near Manchester which receives the sewage of a portion of Manchester. That has an extremely unpleasant smell, in fact sulphuretted hydrogen rises from it. There are people who live upon the banks of it with just the breadth of the towing path between them, and they say that they are in perfect health, and are not at all injured. But it is a remarkable fact, that they

cannot keep meat above a day, even at a time of the year when other people can keep it all the week; they are obliged to use it at once, showing the very powerful influence of this canal, which no doubt must have an influence upon their health, although every person may not feel it to any very perceptible degree. The wet meadows of Milan, we know, give out more injurious matter than the dry lands about."

We can very well understand that a large volume of sewage applied to ploughed lands will be immediately absorbed and disinfected, but we do not place the same implicit faith in grass lands as to their powers of disinfection, and we believe that every blade of grass presents a certain amount of surface on which sewage will lie, and from which it will throw off gases.

The amount of dilution is an important subject, as well as the nature of the sewage constituents. It is well known that urine and excrementitious matter, when it can be collected separately and properly diluted in tanks, is far superior, quantity for quantity, to the generality of town sewage. There cannot either be any doubt that the sewers of large manufacturing towns will contain large amounts of manufacture refuse. The application of manure to crops in a liquid form is in a great many instances more advantageous than when used in a solid form, more especially when applied to green crops. The question, however, of the amount of dilution in the liquid form has either been blinked or has had too little importance attached to it, and thus the term "liquid manure" has been used indiscriminately, not only to represent that collected in farm-yard tanks, but also that obtained from the sewers of towns in which, the supply of water being deficient, the dilution has not been great; and again, to the sewage water of the metropolis and other large towns, where the dilution as compared with the other two cases, may (not unfairly) be termed excessive, being probably six or seven times greater. But to those unacquainted with such facts, the indiscriminate use of the term creates the idea that all liquid manures are equal in value, and hence the statements that have been published as to the very beneficial results of the application of liquid manure should be received with great caution, however truthful the individual statements may be.

There can be no doubt that the flood-waters supplied from a district the land of which is chiefly arable, will produce a much more beneficial effect upon green crops than those from a barren or mining district. In the latter case it *may* be positively injurious. There can also be no doubt that the beneficial effect produced in the first case arises chiefly from the effect of the waters containing the manure that has been washed off the arable lands during

the progress of the floods; the quantum of benefit derived from the application of these waters must, in a great measure, be in proportion to the solid contents of the *fertilizing* matter with which they are impregnated.

It would therefore appear evident that any comparison made between the liquid manure used by the German farmers, that used by the proprietors of the Edinburgh meadows, the beneficial results of which have been published, and the sewer water of the metropolis, or that of New York, where the supply of water is now reported to amount to 90 gallons per head per diem, and those large towns in Great Britain where abundant supplies of water are now afforded, could only lead to error, unless the actual amount of active fertilizing matter contained in such water be first ascertained.

Nevertheless, with all this knowledge upon the subject, the difficulty of applying the sewage water of large towns in a liquid form, so as to produce a commercial benefit, has not been overcome; and the additional experience obtained since 1845 induces the opinion that the difficulties are insuperable, if the system is to be carried out everywhere satisfactorily.

Nevertheless, there are many very intelligent agriculturists who, it may be assumed, from various publications of their opinions, still consider the distribution of the sewage of towns through pipes, by the application of steam-power, and even hose and jet, as a very legitimate method of disposing of it.

To a large extent, any increase of a town supply of water will militate against the value of town sewage, and may involve a commercial loss. It would be reduced in value as a manure, whilst the cost of distribution would be increased; and where there is a question of pumping the sewage, the increased supply of water to populations in the greatest need of it for manifold purposes may be very largely dependent on the disposal of sewage. Is it not possible that the present state of London on this subject may have appeared "satisfactory," because already it was very difficult to ascertain how to get rid of the sewage? The two interests in fact may be in many cases, and are in all to some extent, distinctly and diametrically antagonistic.

Any individual or company interested in the management and disposal of the sewage would probably be energetically opposed to any improvement in an enlarged supply of water, for this might place them in the condition of having a larger quantity of water to carry, and of having their sewage considerably deteriorated by the excess of water. We have already had the best chemical evidence to show how rapidly sewage matter is oxidised by increased quantities of running waters.

The real difficulty that has never yet been overcome, is the large quantity of water that has to be dealt with in almost all cases.

The following value of London sewage is obtained from experiments made by the eminent chemists, Messrs. Hofmann and Witt, and may be taken as fairly representing the average value of London sewage. "The principal valuable constituents in sewage are the nitrogen, which exists partly in the form of ammonia, and partly in the form of organic matter; then, secondly, phosphoric acid; thirdly, potash; and fourthly, organic matter. There are other constituents in sewage, which under particular circumstances, may be of some value, but which, if the question be considered in its general features, may be entirely disregarded. In a gallon we found on an average 6·7 grains of nitrogen, 1·8 phosphoric acid, 1·0 of potash, and 30 grains of organic matter. In estimating the values of the fertilizing constituents of sewage, it would have been impossible to arrive at a correct appreciation if the calculation had been based upon the price at which the individual substances may separately be bought in the market; we therefore ascertained the price of an agricultural commodity in which these substances invariably exist, viz., guano, which at the time when the experiments were made, according to reliable information, was 11*l.* per ton. Now, 100 tons of the solid constituents of the sewage contained, according to our experiments, 7·982 tons of ammonia. A ton of ammonia, bought in the form of guano, possessed at that time a value of 56*l.* per ton. We thus arrive at 446*l.* 19*s.* 10*d.* as the total value of the ammonia. The amount of insoluble phosphate of lime, which per ton was estimated at that time at 7*l.*, contained in 100 tons of the solid constituents, is 1·269 tons: total value, 8*l.* 17*s.* 8*d.* Then comes the soluble phosphate of lime, of which there were 2·631 tons, the value of which being estimated at 32*l.* per ton, adds 84*l.* 3*s.* 10*d.* Then there is one ton of potash, which was estimated at 31*l.* per ton. Lastly, we have 30·11 tons of organic matter, which was calculated at 1*l.* per ton. Accordingly, by summing up, we arrive at 601*l.* 3*s.* 6*d.* as the value of the 100 tons of solid residue of sewage, or 6*l.* 0*s.* 3*d.* as the value per ton. These numbers represent the value of the dry sewage-constituents, including those which exist in the soluble and those which exist in the insoluble state.

"I will now give you the proportionate value of the soluble and insoluble matter. The suspended matter in one ton of solid residue is worth 15*s.* 3*d.*; the value of the dissolved matter is 5*l.* 5*s.*, the whole value being, as I have stated, 6*l.* 0*s.* 3*d.* All the numbers I have hitherto given referring to the solid matter

obtainable on evaporation, it would be perhaps more interesting to the Committee to know the value of the sewage per pound or per ton, such as it is discharged from the sewers: 100 tons of sewage contain, suspended matter, 82·7 lbs., having a value of 2*s.* 2½*d.*; dissolved matter, 245·9 lbs., having a value of 15*s.* 4½*d.* You thus arrive at the result that 100 tons of the sewage have a value of 17*s.* 7*d.*

"This gives the value of the sewage at a little over 2*d.* per ton, remembering of course that it is valued as found in the sewers of a rather dense population, and taking guano as the standard of value, and at 12*l.* per ton.

"I have also calculated the value of total sewage according to the estimation of the rate of flow which was given to me by the referees. They stated that the average quantity of sewage flowing into the river per day in 1857 amounted to 95,000,000 gallons; now, about 220 gallons weigh one ton, and 95,000,000 of gallons accordingly weigh 431,850 tons. Calculating at the price of 17*s.* 7*d.* per 100 tons, the daily value of the London sewage is 3796*l.*, and the annual value, 1,385,540*l.* I may say that we endeavoured to check those results by calculating the value of the fertilizing constituents, which, in the form of fæcal matter and of urine, are discharged by the entire population of London. Supposing these substances to go undiminished into the sewers, we arrive at the value of 1,444,177*l.*, the population of London being estimated 2,600,000."

If sewage runs for any distance exposed to the atmosphere, it would in summer time be altered, some of the substances suffering decomposition; some of the nitrogenous organic matter will undergo putrefaction; but the ammonia exists in so small a quantity that it is not likely to be lost.

If the sewage were to run in an open channel for, say 10 miles, it would not be much altered when the weather is at a medium temperature, but it would in the height of summer. The water of the sewer would not have any powerful action to dissolve the substances dissolved or in suspension; at least not to the extent of altering them materially as regards their agricultural value as manure.

With regard to the bulk of such sewage, which would give a residue of one ton of solid manure, on an average, taking the mean of two experiments, we arrive at about 100 grains of fixed matter per gallon. One ton being the weight of 220 gallons, we arrive at 22,000 grains as the amount of solid matter in one ton of such sewage.

As regards the estimate of the value of this sewage being a fair average for all the sewers in London, Professor Hofmann observes:

"Shortly before the time when we engaged in our examination, similar experiments were made by another chemist on the sewage delivered at the sewers of London Bridge and St. Paul's. The total quantity of matter found by him was 129 grains per gallon, instead of 94 and 111 obtained in our experiments; it is thus seen that there are very considerable discrepancies, as might be expected. M. Verrmann, the chemist, published another result: the Leicester sewage, examined by him in the same summer, left on evaporation 106 grains per gallon. Again, I find the result quoted which Professor Anderson obtained in the examination of the Edinburgh sewage. We found that this sewage left on evaporation 132 grains per gallon, so that the discrepancies are really not excessive; still they might, under peculiar circumstances, vary to a far greater extent.

"With regard to the greatest amount of difference, it may be said that 94 grains is the lowest figure in the experiments which I quoted; 132 the highest figure, which represents the sewage at Edinburgh. I have omitted to mention, however, that I find in my report an analysis by Mr. Way, who examined the sewage taken from the sewer in Dorset-square. He found as much as 209 grains per gallon; this is the highest number which, as far as I know, has been obtained under ordinary circumstances."

And now bearing in mind that we are dealing with the London sewage pumped to a covered reservoir from the outfall of the sewer, and falling from the reservoir through mains laid in the earth at such a depth as to be beyond the reach of the atmosphere, and always full of sewage, and such sewage delivered on the land from a hydrant, Dr. Hofmann considered that through the greater part of the year it would be inoffensive; but in very hot seasons fermentation might set in, and when this has once commenced the inoffensive character is rapidly lost. Also as regards the inoffensive character of sewage applied as manure, it depends on the quantity applied, and the nature of the soil, and the comparative rapidity with which the ground absorbs the sewage. "If you were to put it upon land into which the sewage could not easily penetrate, you could not expect that it would be immediately absorbed; for instance, if you were to put it on land saturated with moisture, the process of absorption would be retarded, and the sewage might then become offensive; but upon land properly treated and properly selected, I think sewage would be rapidly absorbed."

Sewage contains the fertilizing constituents necessary for most crops, being derived from the most varied sources, and representing the mineral constituents of the great variety of plants

which, in that form, have been consumed by men and animals. It can, however, by no means be given as a decided opinion that the valuable constituents of sewage are applicable in all cases without the addition of other manure.

At present, by almost general consent, the practical value of sewage is taken at from 8*s.* to 8*s.* 6*d.* per annum per head of a mixed population, the sewage of wealthy districts being taken at a higher value than in poorer neighbourhoods.

The most useful form of its application may be considered to be a disposition which would enable the farmer to use either exclusively sewage for his purposes, or to use the sewage together with other manures, according to the particular condition of his fields, and according to the nature of the crop he wants to rear.

In the case of Milan, where, although the water used for irrigation receives little or nothing of the solid excrement of the population, and is so dilute that it is hardly to be distinguished by the senses from ordinary stream water, it confers upon the land to which it is applied an increased value of from 4*l.* to 5*l.* per statute acre per annum above that obtained for land irrigated by streams containing no sewage.

At Milan it is put on in very enormous quantities, because the sewage of Milan, so far as there is any sewage flowing at all, flows into the streams, and the whole streams are at command.

With regard to sewage irrigation in a sanitary point of view, it depends very much upon the conditions under which it is carried out. As a matter of course, if there are very large quantities of sewage, people will complain, as in the neighbourhood of Edinburgh, of the offensiveness of it; but we find that in that case the offensiveness is more due to the open gutters than to the sewage itself.

In the Edinburgh meadows the crops, almost entirely grass, are of the richest description, as may be judged from the fact that they are let by auction every year at an average of from 20*l.* to 30*l.* per imperial acre. The works were undertaken, in the first instance, solely with the view of profit, and they have answered so well, that the meadows, some portions of which were formerly a barren sea-sand, are now a very valuable property.

The Edinburgh sewage is considered at least as valuable as that of London, and as much as 8400 tons of sewage per acre is annually put on those meadows at Edinburgh. Assuming that the actual manure contained in the sewage of Edinburgh is worth 2*d.* per ton, 8400 tons would produce 70*l.* 12*s.* worth of solid manure.

Mr. Hemans in speaking of his project for the London sewage makes the following observations:—"The system followed at Edinburgh is very clumsy; the sewage, to begin with,

is in a very different state from what the London sewage is. In consequence of the London sewage flowing through so many miles of pipes and conduits of every description, it is completely churned up, and the solid matter in suspension is reduced to the smallest possible amount; but at Edinburgh the irrigating channels are simply rough ditches dug by hand in the soil, with ragged edges; and as the Edinburgh sewage is full of solid matter of every description, the solid matter sticks in the edges of the channels, and when they are dry it creates a horrible nuisance. But in this case we propose to have tiles with a double lip, and with perfectly smooth edges in which nothing would stick, and one man walking down with a broom would sweep them perfectly clean.

"The irrigation at Craigentinny is carried on in a very imperfect way, as compared with the manner in which it ought to be done; a great portion of the sewage flows over the land; we do not propose to allow any to flow over the land, but merely to put it on in sufficient quantities, and to allow it to sink into the sand below."

In times of heavy rain the quantity of liquid sewage which comes down at Craigentinny is so great, that it is found impossible to deal with it otherwise than by allowing some portion of it to escape into the sea; but with this exception and that of the open ditches, it may be safely asserted that the method pursued at Edinburgh deals with sewage, considered as a thing to be got rid of, with great success.

With regard to the depth of deposit left as soil by the sewage irrigation, it is stated that at Edinburgh, after 40 years, this only amounts to about half inch of deposit. On the subject of the offensive character of the sewage irrigation at Edinburgh, it has been stated that it is the great open permanent carriers only which have this effect; these are said to be 100 years old, and to have accumulated the refuse of years. This observation, however, comes from a staunch supporter of sewage irrigation with large quantities of water.

With regard to the effect of sand on sewage—and the soil of these Edinburgh meadows consists partly of sand,—and the escape of fertilizing matter through these sands, it depends upon the depth of the sand, and upon the quantity the sewage would have to penetrate.

It is not actually filtration. Professor Way observes: "Speaking of sand apart from vegetation growing on the sand, the sand has a peculiar power, which is totally different from the power which clay possesses, of which we were speaking just now, but which is still a specific power of its own, of absolutely

separating salts up to a certain point from solution. Very old observations have been made by Dr. Hale and other philosophers, 200 or 300 years ago, in which the filtration of salt water, for instance, through pots of sand, was found to give water free from salt at all. I do not mean to say, that practically it is of any importance, but according to the quantity of sand it would be of importance.

"Sewage contains everything that you can possibly want on land; I do not say that it contains it in the proper proportions, but undoubtedly, provided the water is not an objection, you might produce with the contents of sewage almost any crop in existence; that leaves the question still open whether the application of the contents in combination with a large quantity of water would be applicable to some crops. Clover, for instance, could be very much improved by sewage."

An error in the application of sewage, besides to natural and artificial grasses, has been the attempt, accompanied by cost, of applying it to every description of crops. It is not that liquid manure does not benefit these crops; on the contrary, it may be applied to them all with great advantage; this has been proved by numerous experiments. In many cases it would be of immense advantage to the farmer to be able to apply sewage manure, especially in the case of turnips and mangolds. But it must be borne in mind that the problem to be solved with respect to sewage is not a simple one. It involves the consideration, how we are day by day to dispose of a large and constant quantity of liquid, which will not bear to be accumulated. The growth of corn, and of green crops, will not admit of a daily application of sewage throughout the year. There are three months at least when wheat must be kept free from moisture to any great extent. Wheat compared to other crops will not take such application beneficially. It is considered that larger returns will be obtained in the shape of crops by putting the sewage over large areas of ground. If we have one million of tons of sewage to put on, and if that sewage is put upon the land in such a way that no portion of it shall run off, or through it, we know that no part of the materials which that sewage contains will be lost; and as anything of that kind fixed in the soil will sooner or later benefit vegetation, we know that in that form of distribution we shall get a larger total produce from a given quantity of sewage than we should by putting it on in large quantities over small areas.

With regard to experiments on the power of soils to absorb the manure contained in sewage, we have the following remarks of Professor Way, who especially on this particular subject is the great authority:—

"The results generally were these, that in soils there resides a power, which previously to my examinations I believe was not recognised, to separate from liquids containing manure, containing ammonia, for instance, and potash and phosphoric acid and magnesia, that is to say, all the important elements of manure, these elements; to separate them from water, not by mere filtration, because these things would pass through a filter, but by the peculiar chemical attraction possessed by the ingredients of a fertile soil for these liquids, so that if we were passing a liquid containing manurial matters through a given quantity of soil, the water would pass through, and these matters would be retained and fixed in the soil. I look upon this as a great arrangement and provision of nature for the preservation of manuring principles from being washed out of the soil by rains.

"After percolation through the land, the water comes out very pure if not put on in very great excess, because of course the power of the soil ceases at a given point; but you may put on sewage in very considerable quantity to the soil, and the liquid running through is perfectly bright and clear, and in a great measure deprived of its inoffensive manurial properties as well as of its offensive ones.

"The minute that it is on the soil, and the liquid has vanished from the surface, there is no sort of smell; if you put it on a fallow soil you would not smell it many minutes after it was applied; if you put it on to grass there would be a certain quantity of it remaining on the grass itself which would not be immediately deodorized.

"I confess that some time ago my belief was that all liquids applied to the soil to deprive them of offensiveness and to get the most benefit out of them should flow through the soil; but it is a fact, which is patent to anybody who has examined the flow of water over soil, in the way that you speak of, that as it flows amongst the roots of grass especially (I am now speaking of a crop of grass being on the land), it leaves behind it its offensive character, and comes off beautifully clear, and to a great extent deprived of its ammonia and other things, which, although manurial, are not offensive. I have seen this in the case of Croydon very lately, although the result does not seem to bear out my statement, an injunction having been granted against the local Board at Croydon.

"So long as it is not in contact with the soil, the soil cannot deodorize it: but if it sinks through rapidly, it will be as rapidly deodorized as it passes through; indeed so much so, that to give you a notion of what the effect of that is, I proposed, a long while ago, that water for the supply of towns should be purified

by throwing it on land properly arranged with under-drainage, because I believe that, except well water, there are many natural waters which may be made purer than they are, and much better for purposes of domestic use, if they are filtered through land, and in many counties you will find that land drainage is actually used by the cottagers for drinking water, and it is very pure."

Many very different values are attributed to sewage of large towns, and particularly to that of London. Professor Way, who has made or seen so many experiments, observes, "with reference to the sewers of London (it is unfortunate that it should be so), I look with very little hope of getting a clear indication of what the sewage of London is, from an examination of the sewers. The sewers, as has properly been said, are mere extended cesspools, in which the sewage runs very slowly, precipitates a lot of its heavier solid matter, and then passes on. At one place there is more of this precipitated than at another, and in time of floods the whole mass is moved again, and goes somewhere else; the consequence is, that you can never get two results which are alike in the case of an analysis of the sewage of London. When it is finally brought to one spot or to two or three spots, and delivered in a regular course, it may be possible to get an examination of it; but there are so many sewers placed under such different circumstances, varying every day and night, and in every week in the year, that I think you can scarcely rely on details. The way in which I prefer to estimate the value of sewage is that it is of such and such composition, or the sewage of so many people; in fact, that there is a certain population, because that is the only direct way of judging of the value of any sewage. If you know that the sewage of one town will fertilize so many acres, you can calculate what the sewage of another town will fertilize; but we have only lately been obtaining the first data by which to calculate the practical value of sewage in reference to the cost of application."

In considering the question of mixing sewage in combination with other manures, there are certain circumstances under which the use of other manures with sewage would plainly be advisable. If you had a small quantity of sewage it would be very desirable to use that sewage as a vehicle of putting on some classes of farm manures; that is to say, if you were using sewage in conjunction with other manures, as you would under any circumstances more or less, then the phosphates are not in such abundance in sewage as would be wanted for some plants. If sewage were used for turnips, it would be desirable to put soluble phosphates into the sewage, and to use it as a vehicle for conveying other manure.

On the question of the change that might take place in sewage after flowing over a long distance, and to which we have already referred, it is the opinion of Professor Way "that all the materials which would be valuable to agriculture would be practically retained by the water, even though they underwent a change. For instance, the organic matters of the sewage in oxidising would give rise to ammonia, which would remain in the liquid; it might be a question whether it might not be a great annoyance, but that is another thing; it might give off quite sufficient material to produce smell, but the question is whether it would lose in power. I think not.

"In the case of rivers purifying so much by running over a long course, you of course have to a very much larger quantity of liquid a very much smaller quantity of the substance to be affected. I do not mean to say that theoretically there would not be any change, but practically there would be none. In rivers you have a very large quantity of oxygen gas dissolved in the water that is constantly changing the organic matter, so that it gets rid of it; in sewage you have on the contrary, large quantities of carbonic acid, which prevent the possibility of there being any quantity of oxygen in that liquid. You will find that the gas, which you see bubble from fœtid pools of sewage, is always carbonic acid gas in large quantity; there are other gases as well, but that prevents the ordinary oxidation which would occur in a river."

The soils to be generally preferred for the application of sewage should be neither too heavy nor too light; a perfectly sandy soil possesses comparatively little of those absorptive properties which have been pointed out, because it is to the clay that those properties are due; but into a heavy clay, on the other hand, it is so difficult to get a liquid, that it would not be brought into action so as for it to get thoroughly impregnated with the sewage. The best soil undoubtedly is a loam, neither too stiff a clay, nor too light a soil.

All lands, at least except deep sands, to which it is intended to apply sewage, should be at least tile drained; on sands or soils that are very light you may put an unlimited quantity of sewage, because it would all pass through quickly, provided there was an escape.

"If you examine the composition of sewage, you will find that by degrees it makes a soil for itself, because the *detritus* of all the roads, at all events in London, is actually clay artificially produced, and much better clay indeed than nature produces for us. We put down ballast in the shape of granite and Kentish rag, and other different stones, in the streets, and we grind them up

into a fine powder; those stones contain all the elements, namely, silica and alumina, potash, magnesia, &c., from which clay has been made by disintegration in the course of ages: we very quickly bring the matter to a practical issue, by grinding the stone by wheels; we have a very large quantity of potash liberated, which goes into the sewers; there have been found remarkable quantities of potash running into the sewers from the London streets, and then the *detritus* is a fine matter which goes down with the sewage in suspension, and which will gradually form a bed of soil for itself wherever it goes."

There is a very great difference between the opinions of two equally eminent and practical men as to the value of sewage, and it is almost impossible to reconcile the different judgments of Mr. Alderman Mechi and Mr. J. B. Lawes.

Mr. Mechi considers that the farmers would be glad to get sewage for their land, and uses the following arguments to support his views: "The cost of putting iron pipes on my farm of 170 acres, so that every part of the 170 acres can be dressed with liquid manure is 2*l.* and a fraction over per acre; that is entirely irrespective of tanks or steam-engines. Therefore, the interest of that 2*l.* at 10 per cent. would be probably the charge for that investment. If sewage from London or from a town were brought near my farm, I would immediately connect my pipes with it; because I have now not only to make my own sewage, at great cost, by feeding animals at a loss, but I have also to make tanks as a receptacle for it, and I have also to employ steam-power at considerable cost to force this sewage on to my fields. But if that line of pipes were connected with a main pipe, having a considerable pressure, which it would have from the elevation to which the liquid would be pumped, I should have nothing to do but to attach my gutter or hose at the end of one of the hydrants, and forthwith we should have our jet without the expense either of steam-power or of tanks, which add 2*l.* per acre to the cost, and add so much beside for the working expenses of pumping it on."

He considers that farmers would find it worth their while to take regular supplies at 2½*d.* or even 3*d.* per ton; "because if it suits me at certain seasons during the summer, when there is growth, to pay 2*d.* per ton for water to wash in guano, which does answer, it will answer to pay (although we should like to have it cheaper) from 2*d.* to 3*d.* per ton for sewage.

"If there were works erected to distribute the sewage there would be no risk of that sewage being refused by the farmers; but it must be by degrees that the people would come to it. I would explain that in this way: the gentleman who took the

Croydon sewage hesitated for a very long period whether he should give 5*l.* an acre, having the command of the town sewage. He visited me; he went to Scotland, and he took a long time cautiously to consider whether it would be worth his while to pay 5*l.* an acre for this sewage land. Mr. Cuthbert Johnson has stated and believes that if that land which Mr. Marriage took four years ago at 5*l.* per acre were now in the hands of the Board of Health of Croydon to re-let, they could let it for 15*l.* an acre. That arises from the observation and from the conviction that the produce is so large as to allow a profit over and above the 15*l.* per acre; that is clear to everyone who knows the price at which the produce is sold, and who sees it cut. The same principle would apply to the farmers who first tried the sewage; one man would take some, and when it was found that it paid him to do so, there would be very little difficulty in persuading others to take it. Moreover, if I could have access to town sewage, instead of having only 15 acres of grass, which is all that I can find sewage for at present, I should have 50 acres, as that is a more profitable system of farming than by purchasing manure. It is simply a matter of cost, profit, and return; but from 15 years' experience I am perfectly satisfied that town sewage is the very thing we want, during the summer months particularly. With regard to the foulness of rivers, we must bear in mind that at present an enormous quantity of manure is washed down from the farmers' farmyards during heavy rains; but I am also sure from observation that the more manure goes into a river up to a certain point the more rapidly will your weeds grow and exercise their purifying influence."

Mr. J. B. Lawes, a member of a commission appointed to make practical inquiries into the value of sewage, has stated, after having made his investigations and experiments, that supposing sewage from a great city like London must be taken off as it arises, and that farmers must take it as it is sent to them every day during the whole year round; that they must pay the cost of subpiping or other means of carriage through their lands, but that it is delivered to them at their farms; under such conditions he maintained, as an experienced agriculturist, after having made special experiments, that they could not afford to give quite so much as one halfpenny per ton. But he considered that if they could take it just when they required it and not otherwise, they could afford to pay twopence per ton, and he would rather give twopence under the latter conditions than one halfpenny in the former.

One hundred and fifty per cent. would certainly tend to prove that however advantageous may be the ordinary plan

of disposing of sewage over lands, there must be a very heavy loss in one respect.

There can be no doubt that Mr. Lawes has given the greatest possible attention to the subject of every description of manure, and that he is in every sense of the word so much of a practical man that we may take his opinion with a considerable degree of confidence, although it is clearly possible that many of these opinions may be modified hereafter as fresh discoveries are made on a subject which is yet far from exhausted.

The tendency of all the recent examinations of sewage has been to reduce the previous estimates of its quality, and more accurate investigations have been made at Rugby. It appears that as the metropolis is becoming more abundantly supplied with water, the sewage is more diluted every year. Mr. Lawes differs very considerably from the estimate of Mr. Alderman Mechi as to the value of sewage, who says that 200 tons of sewage contain as much fertilizing matter as 3½ cwt. of guano; Mr. Lawes thinks that it does not contain half so much.

Where, from any particular conditions, the supply of water to a town is likely to be restricted and to continue so, the value of its sewage will continue to remain much the same year after year, but otherwise the value is likely to decrease, sometimes very considerably. It appears to be a well-founded opinion that the most profitable application of sewage is in the production of grass for feeding milch cows, and that next to that it would be profitable to feed cattle with sewage grass.

In estimating the value of sewage it is necessary to take an annual average value, because generally in a wet year it is much less valuable than in a dry year.

Mr. Lawes is very much in favour of taking the London sewage on to the Essex marshes, and he says that in the interests of the ratepayers the only possible chance they have of obtaining any benefit from the sewage is to deliver it by gravity on a very large tract of ground. He would rather take the low lands, and apply the sewage over them, than pump it to a higher level.

The proposal of Mr. M'Clean, Past President of the Institution of Civil Engineers, was to construct a conduit capable of conveying the whole sewage of the metropolis from the pumping station at West Ham, passing through the rich agricultural districts of Essex to a point on the sea-shore between the estuaries of the Crouch and the Blackwater rivers; this conduit to be made available for the purposes of sewage irrigation throughout its entire length until it reaches the German Ocean.

From West Ham to a place called Battle Bridge over the River Crouch, the conduit would pass through the uplands of Essex, and would be constructed as a tunnel or covered canal. From this place to its mouth it would run through the marshes adjoining the River Crouch, a district almost devoid of population, but extremely rich in agricultural produce, and where upwards of half a million acres of land may receive the benefit of the sewage of the metropolis. For this latter portion of its length it would be sufficient to construct the conduit generally as an open canal, following the course of the river until it arrives within two miles of Burnham, from whence it would be diverted in a north-easterly direction to the sea.

"The proposed outfall sewer would commence by a junction with the one proposed near the pumping station at West Ham, at a point where the high level intercepted sewage and the low level sewage, pumped up, flow through the same channel. The level of the top water at the junction will be 16 feet above Trinity datum, as shown on the plan of your engineer. The conduit would pass over the North Woolwich Railway by means of an iron aqueduct, and under the Tilbury Railway, near its junction with the Eastern Counties Railway; the railway will be raised two feet for the purpose of allowing the water to be maintained at a level 14 feet 6 inches above Trinity datum in the conduit at the time of its maximum discharge. After passing under the Tilbury line it would proceed through Ilford, crossing Barking Creek above the navigable part of the river, and thence, without interfering with the level of any road, to the marsh land near Battle Bridge, in the valley of the Crouch, to which place the tide at present flows. The conduit will be a covered sewer, 24 feet diameter as far as the marshes, from whence, with the exception of a length of about two miles covered near Burnham, it will be an open sewer until it reaches the German Ocean. The fall will vary between five and six inches per mile, and the velocity between two and three feet per second, or between $1\frac{1}{2}$ and $1\frac{3}{4}$ miles per hour, and there will be an uninterrupted discharge at all times of the tide. No pumping would be required between West Ham and the German Ocean.

"The conduit will be capable of discharging 52,000 cubic feet per minute, which is the maximum sewage and rainfall estimated by your engineer to flow through the sewers of the Northern, Southern, and Western districts of the metropolis.

"The sewage of the whole of the southern district may be collected at a pumping station near Southwark Bridge, and be carried by means of pipes over the river to the Aldgate sewer, through which it would flow to the proposed main conduit.

"The expenditure for this work would not exceed 1,600,000*l.*, a sum not greater than the cost of the works required for discharging the sewage into the Thames, even at a distance already contemplated, together with an amount representing the increased annual expenditure for pumping to the outfalls, and for the deodorization of the sewage, but which would be unnecessary if the proposed scheme is adopted.

"In order to prove their confidence in the system now proposed, responsible parties were prepared to execute the new outfall sewer to receive the whole sewage of London, within a period of four years from the commencement of the work, either for the sum of 1,600,000*l.*, to be certified by the engineer of the Metropolitan Board of Works as the work proceeds, or for an annual rent equal to four per cent. of that amount, to commence after the work is ready for use."

We will now venture to make a few observations as to the present state of the outfalls at Barking Creek, because we believe that the whole of the question of the disposal of the London sewage will again demand the attention of the engineering profession.

It is but a few months since Mr. Leach, the engineer to the conservators to the river Thames, made surveys of the river near the great northern and southern sewer-outfalls, in order to ascertain the extent of the formation of extensive shoals. Mr. Leach has ascertained by plans and sections that the deposit of mud is already very extensive.

He states that near the southern outfall the deposit has occurred to the greatest extent on the lower side, where a depth of fully seven feet has been discovered; in front of and above these works there is also a considerable increase.

Near the northern outfall the greatest accumulation appears to be on the upper side; in several places a depth of seven feet has been formed. "It would create no surprise to those acquainted with this part of the river that mud poured in at this spot should have a tendency, as it always has had, to deposit. But it is remarkable that the greatest accumulation has occurred some distance from the outfall on the upper side, and the character of the mud shows clearly enough whence it has come. It has always been put forth as a part of the main drainage scheme that the discharge of the sewage would be so managed, with reference to the flowing tide, that it should not be carried up the stream. The deposit occurring where it has seems to show that the practice which has been observed of running out the contents of the sewers late in the ebb and early in the flood tide must have been adopted to a considerable extent. On the lower side of this outfall there is more of an appearance than there was

formerly of the deposit of small shingle. If this comes from the sewers, as it probably does, the absence of mud is to be accounted for by the operation of the ebb tide and south-westerly winds; the former acting no doubt more freely from the removal of a considerable part of the shoal off the shore of Margaretness. Although these surveys embrace an extensive portion of the river, I have reason to believe that if they were carried further the deposit of mud would still be traceable, and I therefore propose to extend the survey accordingly." Very shortly after the above, Mr. Leach further reported as follows:—

"Since my report of the 10th instant on the deposit which has occurred in the river near the main drainage outfalls, I have had the survey carried lower down, and as it has proceeded the mud has still been met with. At about 1000 yards below the Southern Outfall the deposit takes a diagonal direction towards the northern side, along which it has been traced for nearly 1000 yards, varying in depth to an extreme of five feet. I believe it would be found still lower down if the survey were extended, though to a gradually decreasing amount."

The result of the survey shows that near the Northern Outfall a space of more than 40 acres, and near the Southern Outfall of about 120 acres, of the bed of the river, has been covered by a deposit varying in depth down to seven feet.

The following from Dr. Letheby is, at the least, equally interesting. The mud in each case was black and fœtid, and in a state of active putrefactive decomposition:—

"When examined with the microscope it was found to consist of broken up sewage matter, with the remains of myriads of animalcules, and a large quantity of carbonate of lime in a partly crystalline state. It also contained the usual amorphous matter (ferruginous clay) which gives turbidity to the lower water of the Thames."

"It is evident from this, as well as from what I know of the usual composition of the warp or mud of rivers, that this is a very large proportion of organic matter, and that by undergoing putrefactive decomposition the mud which is accumulating in such large quantities at the sewer outfalls may be a cause for serious alarm, especially as it there meets with sea water, the sulphates of which may by their chemical decomposition by the putrefying mud, occasion the escape of much sulphuretted hydrogen, and set up that remarkably offensive change which is characteristic of the action of sewage upon sea water.

"Lastly, I may state, that the presence of an unusually large amount of carbonate of lime in a crystalline condition, in the mud especially of that of the Northern Outfall, is evidence that

the alkaline constituents of the sewage are decomposing and precipitating the calcareous constituents of the water, and thus adding to the bulk of the deposit."

These conditions are not probably exactly what was generally expected; how far they were anticipated by those who had every opportunity to form sound opinions on the subject, it is of course impossible at present to say; nor how far it was intended that the present outfalls should only be a temporary *débouché*.

The following return by the Metropolitan Board of Works shows the "Amount applied to the Main Drainage Works."

	£	s.	d.
Year ending 25th March, 1860 . .	179,623	5	8
" " " 1861 . .	348,754	7	11
" " " 1862 . .	686,346	17	6
" " " 1863 . .	801,185	8	7
" " " 1864 . .	818,319	7	11
Up to 29th June, 1865 . .	129,623	4	6
	£2,963,852	12	1

The last information of any interest on this subject is a report of the "Works and General Purposes Committee," presented to the Board of Works on the 20th December, 1867, "calling the attention of the Board to the fact that the men employed at the Deptford pumping station had been suffering from a low type of disease, due to the continuous inhalation of the foul air in which they were employed."

In the face of this it may not perhaps be seen how the sewers, which must be the conduits of the said foul air, can be very "sweet," or how it is possible that they should not give off offensive and noxious gases.

The following observations on the "main drainage" are concise and full of meaning: "In the metropolis works of extraordinary magnitude in 'High Level,' 'Mid Level,' 'Low Level intercepting,' and 'River Embankment Sewers,' are now in course of construction, the estimated cost of which works exceeds four millions sterling. The whole volume of sewage on both sides of the Thames being discharged into the river at the points of outlet. These works, gigantic and costly as they are, only imperfectly intercept sewage from the river within the boundaries of the metropolis, to discharge the concentrated volume into the tidal area a few miles nearer the estuary."

The result of this "gigantic" discharge on the bed of the Thames at the outlets in the shape of foul deposits, which can scarcely fail to go on increasing, we have already seen.

I venture to hope a larger amount of professional attention will

be given to the subject of the London water and sewage question, combined with the existing state of the River Thames, because we believe that at present we are considered to have failed in dealing correctly with the subject, and that very shortly the whole of the question must be reopened, not only as regards London, but with respect to all large towns. In India as well as in England, it is found to be the most complicated question with which the engineer has to deal. Year by year for some time past, all large populations have been demanding greater supplies of better water, and in all civilized countries the general request is for a still greater increase; it has been generally supposed that the best mode of dealing with sewage is to convey it away and dispose of it by means of large quantities of water, which however, when the sewage has to be carried a long distance, deprive it of a large portion of its agricultural qualities; we have seen by the best chemical evidence that the larger the quantities of water the more rapidly disintegration takes place; the more rapid also the evolution of offensive gases into the streets. So long therefore as the present mode of dealing with sewage is continued, all increase in water supply for personal cleanliness, domestic purposes, street or house washing, public baths and washhouses, public fountains, and the more effectual means of extinguishing and preventing the spread of conflagrations, would only appear to mean also a more free and ready contamination of the air we breathe, and proportionally a deterioration of the fertilizing properties of the sewage. The ventilation of the sewers, however necessary, is, as generally carried on at present almost everywhere, simply a contamination of the atmosphere, and generally the whole question of sewerage and sewage, as at present treated, is beginning to be admitted simply as *a means of getting rid of the sewage*, perhaps not in the most beneficial manner in any sanitary respect.

Most of us know what marsh fevers are like. The area required for the disposal of the London sewage is considered to be not less than 100 square miles; this would have to be largely increased according to any fuller London water supply. In long wet seasons, by no means very exceptional in our climate, it is difficult to conceive how this extensive area can be otherwise than in a state of marsh, and if the "foul air" of the Deptford pumping station induces "suffering from a low type of disease," we do not see how the sewage spread out over some sixty or seventy thousand acres of land can cause any different sanitary condition of atmosphere. We make these observations without the slightest intention of disparaging sewage irrigation; we merely refer to London, and cities with large populations placed in the like con-

ditions, in reference to which such places as Croydon prove nothing, however perfect the system there may be.

The following observations of Dr. Macadam on the relative values of the sewages of London and Edinburgh bear forcibly on the subject, and demand very serious attention from the engineer in charge of sewerage works in such climates as that of India:—

"The water of Leith, as it leaves Edinburgh, contains fully ten times the quantity of organic matter which is found in the Thames at London Bridge, and necessarily the offensiveness of the water must be correspondingly greater.

"The solid matter discharged by the sewage of London in one day is calculated to amount to 250 tons, and as 50 days elapse before it is capable of reaching Gravesend,* it must by that time have mingled with 250 millions of tons of water, and the oxygen contained therein is no doubt sufficient to aid in the decay or combustion of the organic matter, and thus consume it without putrefaction (in the true sense of the term) setting in. Indeed, before it reaches Gravesend, the greater part of the organic matter must be decomposed, and even at the worst, the water can only have present 12,500 tons distributed amongst 250,000,000 tons of water, which is only two ounces of solid matter in a ton of the water, or $\frac{1}{20000}$th part of the weight of the water. In the investigations relating to the sewage of London and its effects on the Thames, and the injury to health inflicted thereby, it is conclusively shown that the greatest part of the nuisance lies in the sedimentary matter which lines the banks and is in an active state of putrefaction; and the same conclusion has been come to by me in regard to the foul deposits in the bottom of the lades and in the bed of the Water and harbour of Leith.

"The mixture of sea water with the sewage in the harbour of Leith causes, besides the ordinary putrefaction, the production of sulphuretted hydrogen in quantity, and this was specially observable in the mud which was brought up from mid-channel of the harbour by a dredging machine during one of my visits to the Water of Leith. A similar disengagement of sulphuretted hydrogen under like circumstances has been observed previously, especially where organic matter meets with sea water in hot climates, such as on the coasts of Africa, and it has also been observed in part to occur in the Thames, and give rise at least to an increase in the amount of sulphuric acid in combination with Thames water at high tide as compared with low tide. The disengagement of sulphuretted hydrogen in tropical regions when organic matter and sea water meet is so decided that the odour and other effects of sulphuretted hydrogen have sometimes been observed 27 miles at sea from the mouths of rivers.

* By the course of the River.

"The gases evolved during the decomposition of the sedimentary matters lying in the open sewers, the lades, and in the bed of the Water of Leith do not, however, contain much sulphuretted hydrogen (hydrosulphuric acid), but mainly consist of carburetted hydrogen and other combustible gases and vapours which are known to be evolved during the putrefaction of organic matters.

"The gases dissolved in the waters of the sewers, the lades, and the Water of Leith are equally characterized by the minute proportion of sulphuretted hydrogen which is present at any time in these waters, and the amount of which is so slight that in many instances it cannot be recognised. The gases evolved from the decomposing and putrefying deposits rise up through the water which flows above, and pass into the atmosphere, and the liquids also tend to interchange their foul gases with the gaseous constituents of the air, and hence the neighbouring atmosphere becomes contaminated by the evolution of those fœtid gases. The *average* relative purity of thirty samples of the atmosphere collected in districts away from and near the open sewers, lades, and the Water of Leith is given in the following Table :—

"AVERAGE ANALYSES.

Examination of the Atmosphere in the Neighbourhood of the Water of Leith, &c.

Degree of absolute Purity of Air, 100°00.

Place of Collection.	Degree of Purity.
Average of 7 samples of air collected from five stations in Edinburgh and Leith away from the influence of open sewers and of the Water of Leith	76°·71
Average of 2 samples of air collected over the Water of Leith above Coltbridge, and before mingling with sewage	77°·50
Average of 3 samples of air collected from above the open sewers of Edinburgh and Leith	59°·33
Average of 16 samples of air collected over the Water of Leith from Coltbridge down to the Harbour of Leith, and after being mingled with sewage*	60°·37
Average of 2 samples of air collected over the lade of the Water of Leith which traverses Edinburgh and conveys sewage	57°·50"

* One sample of air collected over the Water of Leith, below the dam under Water of Leith village, has not been included in the above average, as its degree of impurity is unusually high, owing to the more rapid escape of the impure gases from the water as it falls over the dam and is dashed into foam. It is tabulated as follows :—

	Temperature.	Degree of Purity.
Air collected over Water of Leith below the dam, &c.	58°	(1) 100° destroyed. (2) 100° destroyed. (3) 100° and only 20 left.

The following observations by Dr. Macadam on the subject of Edinburgh and the Water of Leith are amongst the most interesting we have ever read, as addressed to the Engineer in charge of Sanitary matters; and the more so that we think many of them bear upon the deposits accumulating in the bed of the Thames at Barking Creek, though we do not in the least wish to convey the idea that there is any similarity as to quantity or extent. They are also highly interesting to the professional man in regard to the manner in which several of the experiments were made:—

"*The Sedimentary Matters in the Bed of the Water of Leith.*

"The solid matters which the sewers of Edinburgh and Leith carry in mechanical suspension into the Water of Leith are deposited in large quantities in ordinary seasons in the pools or cavities in the rocky bed of the stream, and also at the bottom of the still water which is found above all the six mill dams or cauls.

"Immediately below the entrance of the Lochrin Burn into the Water of Leith at Coltbridge a bank of deposit of decomposing solid sewage matter, several feet in depth, lies putrefying and exhaling foul gases, and from this point to the mill-dam at a short distance below, the fermenting sediment is more or less deep, and indeed from this station down to the harbour of Leith, the bed of the Water of Leith, including the part where the channel is narrowed, and also the bottom of the lade, are covered more or less thickly with putrefying sediment. This was specially observable—

"1. At the dam below Water of Leith village, where the foul deposit consisted, on the average of four samples, of 48 per cent. of organic matter containing nitrogen, and was in a state of active putrescence.

2. In the numerous pools in the rocky bed of the Water of Leith behind Moray and Ainslie Places, where the putrefying stuff is often two feet in depth, and contains, on the mean of two samples, 45 per cent. of organic matter with nitrogen.

3. In the bed of the Water of Leith, below the North and South sewers at Stockbridge, where the average of eight samples washed up upon the banks gave 43½ per cent. of organic matter, a sample taken from the sides of the narrowed channel gave 34½ per cent. of organic matter; a sample collected from the bottom of the narrowed run, 80 yards below Stockbridge, gave 25 per cent. of organic matter; and still further down, at Malta Terrace, the

sediment in the bottom of the run gave 32½ per cent. of organic matter. In all of these instances the organic matter was, as usual, of an offensive and putrescent nature, and contained a decided proportion of nitrogen, &c. &c.

"In the harbour of Leith the putrefying deposit is diffused through a depth of one to two feet, and is necessarily mingled with fine sand brought in by each tide. Samples of the deposit were collected at all the principal points on both sides of the harbour, and they were taken at a little distance from the banks so as fairly to represent the condition of the mud or deposit in the harbour. When the tide was out, it was observed that the whole bed of the harbour was composed of a black-coloured slimy foul deposit. Twelve samples of the sedimentary matter lying towards the S.E. side of the harbour gave an average of 28⅓ per cent. of organic matter containing nitrogen, and 6 samples collected towards the north-west side of the harbour gave an average of 20 per cent. of organic matter with fully 0·60 of nitrogen.

"These sedimentary deposits found in the river of Leith, from Coltbridge downwards to the harbour of Leith, and in all the mill lades connected therewith, are undoubtedly due to the discharge of the sewage of Edinburgh and Leith into the Water of Leith and the lades, and are not only foul and unsightly in themselves, but are far more noxious as hotbeds for the disengagement of unwholesome gases. The rapidity with which the gas escapes from these organic muds is such that at the dam heads and in the harbour, the water floating above the putrefying stuff is perforated every moment with bubbles of gas, and so abundant are these that in many places the water presents the appearance of being in a state of ebullition.

"*The Gases evolved from the Muds or Sedimentary Matters.*

"The gaseous emanations from the putrefying deposits in the bed of the Water of Leith, the lades, and the harbour, have received special attention in their examination. These gases are evolved more or less rapidly according to the depth of the organic mud and the temperature of the season, and hence, in summer weather, the putrefactive processes proceeding more quickly, give rise to the disengagement of much gas even when the sediments are kept at rest, and lead to the evolution of large quantities whenever the deposit is agitated by a rod. In the bed of the Water of Leith, especially at Coltbridge, behind Ainslie and Moray Places, at St. Mark's Place down to the dam above Bonnington, at Bonnington Bridge, at the dam above Junction Road Bridge, and in the harbour of Leith, the dis-

engagement of bubbles of gas is incessant, and resembles a shower of rain falling. In the part of the Water of Leith where the channel is narrowed, as also in the lades, the evolution of gas is not so readily observed owing to the rapidity of the run of the water, but the slightest agitation of the bottom of the confined channels of the stream or of the lades at once causes the rapid disengagement of gases, so that there is no difficulty at any part of the Water of Leith from Coltbridge downwards in obtaining a good supply of gas for the purpose of examination as to its chemical composition.

"In the collection of the gases, a bottle was filled with the water which was flowing over the deposit, and being inverted under the water with a funnel attached to the mouth, the sediment was agitated, when the bubbles of gas rose, and entering the bottle displaced the water. A glass stopper luted with lard was inserted into the mouth of the bottle whilst under the water, and within three hours of the collection of the gases, the per-centage composition was determined by analysis. The results of the chemical investigation showed that the gaseous emanations mainly consisted of gases which were combustible with a blue-white flame, accompanied by smaller proportions of carbonic acid and oxygen. The proportion of the latter gas was small, and there is little doubt that some at least of this oxygen may be regarded as derived from the gases dissolved in the water used in the collection and examination of the samples of air under analysis. The carbonic acid was determined by absorption with potash, and the oxygen was ascertained by the use of pyrogallic acid and potash, whilst the remaining gases were merely brought into contact with a lighted taper, and were observed to burn with a blue-white flame. The combustible gases which are well known to be evolved from decomposing plant and animal substances during putrefactive decay, are marsh gas or light carburetted hydrogen, hydrogen, and carbonic oxide, and from the fœtid odour of the residual gas in all of the experiments, I have no doubt that these were accompanied, in the gases collected by me from those deposits of mud, by smaller proportions of other gaseous substances of a foul and noxious nature. In the majority of instances no traces of sulphuretted hydrogen were obtained when lead paper was introduced or when the odour of the gas was tried, but in the gases evolved from the sediment in the Water of Leith behind Warriston Crescent in Edinburgh, and that between the upper and lower drawbridges in the harbour of Leith, as also in those evolved from the mud off the jetty head at the entrance to the Victoria Dock, decided traces of sulphuretted hydrogen were obtained.

"Fourteen samples of gas collected from sedimentary matters were examined. One sample of gas was taken from the mud or deposit in the Lochrin Burn sewer; two samples from the sediment in the bed of the Water of Leith at Coltbridge; two samples from the bed of the Water of Leith behind Moray Place; two samples from the sediment in the lade behind India Place; one sample from the bed of the Water of Leith below Stockbridge; one sample behind Warriston Crescent; two samples from St. Mark's Place; one sample from the dam at Junction Road Bridge; one sample from between the upper and lower drawbridges, and one sample from off the jetty head at the entrance to Victoria Dock. The proportion of carbonic acid in the gases ranged from 1·56 to 25·60 per cent.; of oxygen from 0·32 to 2·17 per cent.; and of other gases which were combustible with a bluish-white flame from 72·60 to 97 per cent.

"The experimental results on the composition of the gases evolved from sedimentary matters in foul burns and waters teach the important doctrine, that the escape of sulphuretted hydrogen may scarcely, if at all, be recognised, and yet large quantities of combustible gases, undoubtedly of organic origin, may be disengaged into the surrounding atmosphere, and consequently that the contamination of the air may occur without sulphuretted hydrogen being observed.

"During the progress of these experiments attention was directed to a green substance consisting mainly of *Euglena viridis*, one of the Phytozoa, which was observed on the surface of the stagnating mud at the side of the Lochrin Burn, and in shallow parts of the Water of Leith, as at St. Mark's Place, and which was said to neutralize in great part the deleterious effects of the gaseous exhalations, and even to lead to the disengagement of oxygen gas in large volumes. A considerable quantity of the green slime was separated as well as practicable from the underlying filthy sediment, and having been placed in a bottle till it was filled, the bottle was then inverted in a basin, and immediately gases began to be evolved. On testing these gases in about three hours, there were found carbonic acid 13·40 per cent., oxygen 1·60 per cent., and other gases, which were combustible with a bluish-white flame, 85 per cent. It was proved, therefore, that this green slime does not practically lead to the disengagement of oxygen, and indeed the gases which are evolved therefrom are essentially identical with those obtained from any foul deposit in a sewer or in water conveying sewage.

"Moreover, the green slime, when collected from the surface of the sedimentary matter, and placed in a bottle which it filled about one-third, and the remaining two-thirds being left as

common air, it was found that in forty hours the composition of the atmosphere had so materially changed that a lighted taper was immediately extinguished on being introduced. A chemical analysis proved that the atmosphere left in the bottle contained 11·56 per cent. of carbonic acid, only 2·01 per cent. of oxygen, and 86·43 per cent. of other gases, which in their mixed state were not combustible and did not support combustion. These two experiments, therefore, demonstrated that practically the evolution of oxygen gas from the green slime covering a mass of putrescent filth was at a minimum and was highly problematical, whilst the disengagement from the mass of carbonic acid and of combustible gases was undoubtedly certain. The green slime on being examined microscopically was found to consist mainly of minute organisms belonging to the *Phytozoa*, and which are alternately regarded as animals and plants. At present the *Euglena viridis*, which forms a part at least of the green matter of these deposits, is considered to be a plant by some naturalists, and an animal by other authorities.

"*The Gases dissolved in the Waters of the Sewers and of the Water of Leith, &c.*

"In all good natural waters there is present in solution a greater or less proportion of gaseous matter which the water has in great part dissolved out of the atmosphere. The gases present in healthy waters are carbonic acid, oxygen, and nitrogen; the two latter being in largest quantity, and the relative proportions of these two gases are, that for one volume of oxygen there are two volumes of nitrogen. These are not the proportions in which oxygen and nitrogen are present in the atmosphere, where there are for one volume of oxygen four volumes of nitrogen; but the greater solubility of oxygen than of nitrogen in water admits of a larger proportion of oxygen dissolving in the water, relatively to the amounts of these gases in the atmosphere.

"Two important offices are fulfilled by the oxygen which is dissolved in natural water. In the first instance, it supplies the air which fish require for their respiration, and without a due supply of which the fish become asphyxiated and die; and, in the second instance, it oxidizes any organic matters which pass into the water, and thus tends to purify the stream. It may be at once stated, however, that there is a certain limit to the power which oxygen possesses to consume organic matters, as in the act of doing so the oxygen enters into union with the elements of the decaying organic matter, and therefore ceases to be free oxygen, and cannot be recognised as such in the water. Moreover,

whenever the oxygen has been used up in the decomposition of the organic matter, and there is still some refuse plant or animal substance left in the water, then putrefaction must follow and consequently foul gases be evolved.

"The manner in which the oxygen dissolved in water acts upon foul matters contained therein may be observed from this, that organic substances principally consist of carbon, hydrogen, and oxygen, accompanied by a smaller proportion of nitrogen and minute quantities of sulphur and phosphorus; and where there is oxygen dissolved in the water sufficient to act upon these, it oxidizes the carbon into carbonic acid, the hydrogen into water, the nitrogen into nitric acid, the sulphur into sulphuric acid, and the phosphorus into phosphoric acid. Whenever the proportion of oxygen becomes exhausted, then the organic substance still lying beneath as sedimentary matter, or still floating along with the water, cannot be oxidized, and must seek the elements of change within itself, and give rise to the disengagement of those combustible and foul gases which are characteristic of the putrefaction of refuse animal and vegetable substances.

"In the examination of the gases dissolved in the waters of the sewers of Edinburgh, and of the Water of Leith, &c., I analysed the gases from 25 samples of water. The spring-water which is conveyed to Edinburgh in pipes for the service of the city, gives as the results of these separate analyses from 9·33 to 10·01 cubic inches of gas dissolved in one imperial gallon, and the per-centage composition of these gases is, carbonic acid 8·70 to 10·71, oxygen 28·77 to 29·47, and other gases (nitrogen) 59·82 to 61·90. The proportions of oxygen and nitrogen therefore are nearly 1 to 2, and the average amount of oxygen is fully 29 per cent. The two main feeders of the Water of Leith are the Harelaw reservoir, which flows into the Bavelaw Burn, and the Water of Leith, and as the oxygen is the principal gaseous ingredient, I will simply mention here that the per-centage of oxygen in the gases dissolved in the water of the Harelaw reservoir is 29·23, whilst in the other feeder—viz., the upper part of the Water of Leith, the per-centage of oxygen is 28·87. A sample of water collected at Currie Bridge, after the discharges from various works had passed into the stream, gave 22·06 per cent. of oxygen, and another sample of water collected still further down, at Georgie Bridge, on a different day, gave 25·20 per cent. of oxygen, whilst two samples taken at different times from the Water of Leith at Coltbridge, just before mingling with the sewage of Edinburgh, gave respectively 22·22 and 22·20 per cent. of oxygen. It is thus evident that all the discharges thrown into the river in its upper parts, from the paper mills and other public works, are sufficient

only to reduce the per-centage of oxygen from 29 to 22, and there is practically enough of oxygen still left in the water to oxidize more organic matter. The actual amount of oxygen taken up by the oxidation of the organic matters discharged from the mills may, however, be relatively greater than what is represented by the proportional difference between 29 and 22, as during its course down to Coltbridge the Water of Leith is exposed to the air, is, moreover, at certain parts a rapid running stream, and occasionally flows over a rocky bed, and thus the water is liable to become aërated again, and will likely, as it loses oxygen in the oxidation of the organic matter present in the water, receive a fresh supply from the atmosphere. At all events, the Water of Leith arrives at the outskirts of Edinburgh, and at the point where the first portion of the sewage is discharged into it, as a stream which still retains enough of oxygen to keep all its other ingredients in a fresh condition.

"Three samples of liquid were taken from the sewer known as the Lochrin Burn, one sample from the South or Moray Place sewer at Stockbridge, and one from Canonmills sewer, and the amount of oxygen present in each of these respectively was 3·33, 2·70, 2·10, 2·80, and 2·60 per cent. In other words, the proportion of oxygen was at a minimum, and it is questionable how far the remaining traces could have the power of oxidizing organic matters. At all events it was plainly observable that the spring water which is conveyed into the houses of Edinburgh, with oxygen present in the gases dissolved therein to the extent of fully 29 per cent., is afterwards found escaping from the sewers with the proportion of oxygen less than three per cent. on the average of five samples. Moreover, the sewage liquids were highly charged with organic matters capable of being oxidized, and possessing the power of abstracting the oxygen dissolved in very large quantities of water.

"The effect of the sewage matters on the gases dissolved in the Water of Leith is very decided, for whilst the gases in the Water of Leith at Coltbridge contain fully 22 per cent. of oxygen, the sewage conveyed by the Lochrin Burn, and numerous smaller sewers discharging into the stream, has the effect of reducing the per-centage of free oxygen to 4·20 per cent. by the time the water passes down to the Water of Leith village, and much organic matter still remains dissolved and suspended in the water of the stream. The water then finds its way over a rocky bed, and apparently it becomes aërated anew to some extent, for under the Dean Bridge the per-centage of oxygen in the gases has increased to 5·70, and behind Moray Place, near St. Bernard's Well, to 6·10, whilst on another occasion the proportion rose to 10·20 per

cent. As the stream flows on, the aëration process proceeds, counterbalanced, however, by the oxidation of the organic matters already present, and being received every here and there, the proportions of oxygen fluctuate from 6·60 to 4·10 near Stockbridge, and at St. Mark's Place, after the lade joins, from 6·98 to 4·10. The gases dissolved in the waters of the lade which traverses Edinburgh, gave at India Place, on two different occasions, 4·76 and 6·40 per cent. of oxygen, and the water of the lade, just before joining the Water of Leith at St. Mark's Place, gave 5·40 per cent. of oxygen.

"These experimental data afford proof that whilst the water of the Water of Leith arrives at Coltbridge charged with oxygen, that immediately on mingling with the sewage of Edinburgh conveyed by the Lochrin Burn, the proportion of oxygen is reduced to a minimum, and practically the Water of Leith and the lade traverse the streets of Edinburgh destitute of the power of oxidizing the organic matter discharged into it by the numerous drains and sewers. The result is that true putrefaction proceeds, and noxious gaseous exhalations are evolved from the decomposing organic matters. Under no circumstances is oxygen evolved from the decomposition of animal and vegetable substances, and as there is practically no purifying agent left in the Water of Leith, the extensive deposits of organic muds, which are found here and there and everywhere in the bed of the stream and lade, have no oxygen to consume or burn them, and are left to putrefy and exhale fulsome emanations.

"*The Atmosphere in the Neighbourhood of the Water of Leith, &c.*

"The gases evolved from the decomposing matters were generally recognised in the immediate vicinity of the Water of Leith conveying the sewage, as also in close proximity to the main drains or sewers. The odour was not that of sulphuretted hydrogen, but a heavy fœtid nauseous odour, specially observable immediately over the stream, and was doubtless due to the escape of gases produced by the putrefaction of the organic deposits. The state of the atmosphere was not only judged of by the test of the nose, but special experiments were made with a standard solution of permanganate of potash, so as to determine the relative purity or impurity of the atmosphere in the vicinity of the Water of Leith, and at some distance therefrom. The employment of the permanganate of potash for the detection of impurities in the air was first suggested by Dr. Angus Smith of Manchester. The standard solution which was used in making the analyses of the air in connexion with this inquiry was of such a strength that

250 grains, by measure, of the permanganate of potash solution decolorized by 0·027 of a grain of fruit sugar, and the same quantity of permanganate was decolorized by 0·0075 of a grain of metallic iron.

"In the collection of the samples of the atmosphere at various localities, half gallon stoppered bottles were taken, and after being rinsed with sulphuric acid and nitric acid, were thoroughly washed with water, treated with a little permanganate of potash, re-washed with distilled water, and then filled with pure water and the stoppers inserted. When the bottle was intended to be filled with air a siphon was introduced to the bottom of the bottle, and the water being run off by the siphon, the air entered at the mouth of the bottle without being washed by the water. The bottle was re-stoppered and the contents were tested as quickly as possible.

"In using the standard test solution of permanganate of potash for the examination of the air, an improvement in its mode of application was suggested by Dr. Penny, and carried out in these investigations. Instead of employing the coloured solution, little by little, so long as the colour was destroyed, which leads to great irregularity in the length of time of agitation, and is, moreover, tedious, a series of standard tubes were filled with solutions of the permanganate of potash of varying strength, so as to form a sliding scale, where the full or undiluted colour was No. 1, and the succeeding numbers contained more and more water till No. 11 was nothing but water. The following short table will exhibit the scale which was adopted as the test standard:

"Test tube.						Degree in scale.
No. 1	contained	250	grains	of the solution of permanganate of potash, and	no water	100
,, 2	,,	225	,,	,,	25 grs. water	90
,, 3	,,	200	,,	,,	50 ,,	80
,, 4	,,	175	,,	,,	75 ,,	70
,, 5	,,	150	,,	,,	100 ,,	60
,, 6	,,	125	,,	,,	125 ,,	50
,, 7	,,	100	,,	,,	150 ,,	40
,, 8	,,	75	,,	,,	175 ,,	30
,, 9	,,	50	,,	,,	200 ,,	20
,, 10	,,	25	,,	,,	225 ,,	10
,, 11	,,	0	,,	,,	250 ,,	0

"The mode of testing the air in the bottles consisted in adding 250 grains by measure of the standard solution of permanganate of potash, and agitating the test solution with the air for five minutes, when the solution was poured into a test tube, and the depth of colour still remaining observed, and contrasted with that of the solutions in the standard test tubes. If one half of

the colour was lost, the liquid from the bottle would resemble in depth of tint that in test tube No. 6, which contains 125 grains of the permanganate of potash solution, along with 125 grains of water, and the degree in the scale of purity would be 50; absolute purity being 100, and the complete decolorization of the liquid being 0.

"Thirty-one samples of air were collected at various parts on different occasions and were tested. On the 7th April, nine samples were tested, and whilst the degrees of purity of the air at three stations in Edinburgh away from the influence of the Water of Leith were respectively 100 (being absolute purity), 85, 70, and 67, and the air at the Water of Leith at Coltbridge, before being mingled with sewage was 75, the atmosphere in the immediate vicinity of the sewers and of the Water of Leith conveying sewage had its degree of purity reduced to 63, 58, 55, and 55, and in one instance, as below the dam under the Water of Leith village, the 100 of standard colour was totally destroyed, a second 100 was similarly bleached, and of a third 100 only 20 remained. The reason of the very impure state of the air at this point lies in the fact that the water conveying the sewage, in falling over the dam, is dashed into foam, and the impure gases tend more quickly to escape, and thus contaminate the surrounding atmosphere to an extent more than in ordinary circumstances.

"On the 9th April 16 samples of air were collected and examined. Three samples taken in Edinburgh in places away from the Water of Leith, and one sample collected in Leith at a distance from the polluted stream, gave respectively the degrees of purity of 80, 75, 80, and 80, and one sample taken from the harbour at the Victoria Dock head gave 70; whilst the air collected under the immediate influence of the Water of Leith, conveying the sewage of Edinburgh and Leith, gave respectively 60, 60, 50, 60, 60, 55, 55, 55, 60, 50, and 55. On the 14th April six samples of air were collected and examined, when it was found that over the Water of Leith above Coltbridge, and before mixture with sewage, the degree of purity was 80, whilst over the sewers, and the Water of Leith conveying sewage, the degrees of purity were 68, 66, 70, 64, and 70 respectively.

"These experimental results demonstrated that the atmosphere in the immediate neighbourhood of the Edinburgh and Leith sewers and the Water and Harbour of Leith contains more impurity than what is present in those parts of Edinburgh and Leith which are away from the influence of the foul gases emanating from the putrefying substances in the Water of Leith.

"The Vegetable and Animal Life in the Water of Leith, &c.

"In the bed of the Water of Leith above the influence of sewage, as at Georgie dam, which is about a mile above Coltbridge, the stones over which the water flows have plants, such as moss, attached to them, and these plants are found on the stones in the bed of the streams conveying water practically free from putrescent matter; but from the entrance of the Edinburgh sewage at Coltbridge downwards to the harbour of Leith, the stones in the bed of the stream are covered with offensive organic growths, which are characteristic of waters conveying sewage and capable of decomposing and evolving unwholesome gases. Indeed, not only are the stones covered with such vegetable growths, but everything in the bed of the river, such as arrested portions of trees, becomes thickly coated. They are also seen in the sewers called the Lochrin Burn sewer, the Broughton Burn, and the Bulls Stank sewer at Lovers Loan as it leaves Edinburgh, in all of which the bottom and sides are more or less covered with the growths. Even in the narrowest part of the channel of the Water of Leith, where the run of water is great, these organic matters are abundant, and likewise in the bottom and sides of the lade which traverses Edinburgh. All the twigs and branches of trees which hang down into the Lochrin Burn sewer, and into the water of the lade, as from the gardens behind Ainslie Place and Moray Place, have these growths adhering in long streamers, rendered bulky and doubly foul by the accumulation of entangled filth. These growths principally consist of those low forms of vegetable life which are regarded by some naturalists as *Fungi*, and by others as *Algæ*, and they are accompanied by masses of animals belonging to the family of *Vorticellidæ*, including the genera *Vorticella, Carchesium, Zoothamnium*, and *Epistyllis*. Much of the organic matters which are found entangled in the branches of trees hanging into the lades and open sewers, as also of the organic deposits which are found in the beds of the Water of Leith and of the lades, are composed of the decaying remains of such growths.

"The chemical analyses of these organic growths demonstrated, that even when examined with all the adhering entangled filth, when dried, they contained, on the average of seven samples, 50·61 per cent. of organic matter, of which 0·84 consisted of nitrogen. These organic matters are being constantly detached from the stones, &c., on which they grow, and the torn off fragments float down the stream or lade and form part of some deposit in a rocky pool or in the still water above a dam. A considerable proportion of the deposits observed in the bed of the

Water of Leith behind Ainslie Place and Moray Place, and in the large cesspool at St. Mark's Place, consisted of those organic growths passing into an active state of putrescence. During the spring months the growths are apparently stronger and form longer streamers than during the summer months. The temperature of the latter is higher, and facilitates changes such as the disintegration of the mass. These growths appear to be the last stage of organic life which will inhabit foul water, but in places where in the spring many patches of the growth were observed, in summer hardly any was to be noticed. This disappearance, in part at least, of the growth is to be attributed to the more foul state of the sewers and Water of Leith in summer, which leads in some places to such a rapid putrefaction as even to arrest the development of this comparatively simple form of organic life.

In the whole course of the Water of Leith from Coltbridge downwards not a single fish could be seen. The animal life which was specially visible to the naked eye consisted of colonies of small red worms, which were very abundant in many places, and are regarded as the last remnant of animal life which will exist in water contaminated by sewage. These minute red worms are a kind of *Nais*, belonging to the family of *Naidina*, and are named *Tubifex rivulorum*. They are found in greater abundance in the Water of Leith during spring than in summer, apparently from the more active putrescence of the sedimentary matter leading in the summer to the disengagement of a more full supply of noxious gases which even those minute worms cannot survive. In many places, where in spring the bed of the stream or of the lade harboured myriads of even this inferior type of animal life, there was hardly a specimen to be had, and this was doubtless due to the more rapid putrescence of the deposits. Abundance of animalculæ, including the *Paramœcia*, were found in the Water of Leith at all seasons of the year.

One curious effect of sewage upon animal life was observed by me in the harbour of Leith. Two wooden piers stretch some distance into the sea; they are constructed of the same kind of timber, and are of the same age. The West pier is not influenced by sewage passing down the harbour, as the tide sweeps the sewage from it; and the wood of this pier is nearly eaten through in some parts by the *Teredo*, a bivalve (Lamellibranchiate) mollusc, which is well known to be destructive to wooden erections in the sea. But the East pier is washed by the sewage water, and, apparently from the disengagement of sulphuretted hydrogen which is specially formed when sewage meets sea water, there is not a single *Teredo* to be seen at its work of

drilling holes in the wood. The sewage in such circumstances, therefore, appears to be beneficial in retarding the ravages of this troublesome mollusc.

Independently of the putrefaction of the sedimentary deposits fish might live in water which contained nearly the proper proportion of oxygen, but the water of the Water of Leith from Coltbridge downwards is almost devoid of oxygen, and fish can no more live in water containing no oxygen than land animals could live in an apartment destitute of air.

The following most valuable notes on the sewage meadows of Edinburgh and Croydon, have been given by able Sewage Commissioners in their third and last report.

"The following statements relating to the sewage-irrigated meadows in the neighbourhood of Edinburgh are based partly upon information obtained on the spot from Mr. McPherson, the city surveyor, and from the occupiers or managers of the meadows in the respective localities, and partly upon correspondence with the latter gentlemen. Mr. McPherson kindly provided information as to the population, water supply, springs, and area of rainfall and drainage, contributing to each set of meadows as named or classed together in Table I. below; and from the occupiers or managers, information as to the area under irrigation, and other points, was obtained. As, however, the sewage is in no case passed over the land the whole 365 days and nights of the year, it must be borne in mind that the statements given as to the amount of population contributing to, and the number of tons available for, each acre, do not show the amounts actually utilized in each case, but only approximately the total amounts available, whether used or wasted. The fact that water-closets are not universal must also be taken into account.

TABLE I.

Names of Meadows.	Imperial Acres under Irrigation.	Approximate Population contributing to each Acre.	Approximate Quantity of Sewage available for each Acre.
			Tons.
Lochend, Spring Gardens, and Craigentinny	285	337	20,500
Roseburn and Western Dairy	80	112	17,000
Quarry Holes.	8	562	65,000
Broughton Burn	6	1,666	102,000
The Grange	16½	302	97,000

1. *Lochend and Spring Gardens.*

The Lochend and Spring Gardens meadows, occupied by Mr. Scott, and under the management of Mr. Peter Taylor, comprise about 35 imperial acres, and are irrigated by the sewage of a large portion of Edinburgh on its way to the more extensive Craigentinny meadows. Mr. Taylor estimates that, on the average, each acre gets the flow of a stream of 12 by 8 inches, at a rate of 2 miles per hour, for 10 days of 16 hours, annually, which is equal to about 31,000 tons per acre per annum. The sewage is applied from about the beginning of March to the end of November. The herbage consists chiefly of rough meadow-grass (*Poa trivialis*), which is the most prevalent where the ground is dry, and couch (*Triticum repens*), which is the second in predominance, and grows freely, but is not so early as the rough meadow-grass. There is also a great deal of crow-foot, more particularly where the drainage is imperfect.

On a portion of higher lying land, which is irrigated by the aid of a water-wheel, worked by the sewage stream itself, and where the supply is necessarily more limited, Italian rye-grass is grown, which involves the periodical breaking up of the land. After two years under the rye-grass a crop of potatoes is taken, then Italian rye-grass is sown again, and so on. Mr. Taylor stated that if this land could be irrigated by an abundance of sewage by gravitation he should prefer to lay it down as permanent meadow.

2. *Craigentinny.*

The meadows at Craigentinny, which are the property of Mr. Christie-Miller, are under the management of Mr. Bryce. About 190 acres of permanent meadow are irrigated by gravitation. A portion of this area consists of a good loamy soil, but a part of it was only barren sand before it was laid down for sewage irrigation. During the summer the sewage is applied day and night, and all that is available is then used, excepting during floods. The sewage is also applied through a considerable portion of the winter, but then during the day only. Perhaps it is unused 70 to 80 days in the year. The general plan during the summer is to let the whole of the water go over from 2 to 2½ acres at a time, changing every 3 or 4 hours during the day, but less frequently during the night; and the application is so timed as to get over, on the average, about 60 acres per week, and to give each acre such a dressing about once in three weeks. The applications are, however, less frequent during the winter. The distribution over about 100 acres can be attended to by one man;

but the cleaning of the runs, keeping the roads, &c., require additional labour. Four to five crops are obtained annually; though four, cut at the proper times, generally yield better, and leave the herbage in better condition than when five are taken. From good, well-managed meadows, with sewage as liberally applied as on the gravitation meadows at Craigentinny, Mr. Bryce thinks about 60 tons of green grass should be obtained per imperial acre annually. The price varies according to season and other circumstances, from 6*d.* to 14*d.* per cwt., on the ground, standing. The produce consists almost entirely of rough meadow-grass, which is considered the most valuable, couch, which is looked upon as a very good grass and of very rapid growth, and common rye-grass, which is also considered a good grass, but not to give so close a bottom as the others.

Arrangements are also made for irrigating some higher-lying land, by raising the sewage about 20 feet, it being first brought into a large tank by means of a deep underground drain from the highest level of the natural flow, and thence pumped into open channels for surface distribution. Only about 60 imperial acres are now so irrigated, but formerly a larger area was under the treatment. The application is continued from April to October inclusive; and each plot gets six dressings, and yields three cuttings, annually. If it were not for the cost of lifting, more of this land would be laid down as permanent meadow, and much more sewage would be put upon it; but the supply being so limited by the cost of application, Mr. Bryce thinks it better to sow Italian rye-grass, break up every two years and grow potatoes, re-sow rye-grass, and so on.

3. *Roseburn and Western Dalry.*

These meadows, situated to the west of the city, stand second in point of extent and importance to those of Craigentinny. They formerly comprised 100 imperial acres or more, but are now limited to about 80, having been considerably curtailed by the encroachments of railways, and for other purposes; and as much as 1000*l.* per acre has frequently been paid as compensation. They were laid down for irrigation by Mr. James Thomson, who commenced his operations in 1826, and they still continue under his excellent management. Part of the soil is gravelly, and part loamy, with a subsoil of clay. The sewage coming to these meadows includes the refuse from extensive slaughter-houses, and also that from a very large distillery. It is used all the year round, both day and night, and on Sundays, when it can conveniently be left to flow from Saturday night to Monday morn-

ing. In summer the water seldom goes over the same piece of land more than a few hours together—as long as may be necessary thoroughly to soak it. The land is generally watered only twice, but occasionally three times, between the cuttings. In winter the water is allowed to flow for a longer period over a given area, in order to "feed" the land as much as possible. In laying down permanent meadow for irrigation, Mr. Thomson has sometimes sown a great variety of grasses, but finding that even when he has sown 15 or 20 different kinds, most of them have in the course of a few years gradually died out, leaving only those suitable to the soil and the sewage, he sometimes selects only three or four, and in one instance transplanted couch from arable land, and reports that the piece so treated is now as good as any.

4. *The Grange.*

Next in extent to the Roseburn and Dalry sewage meadows come those of the Grange, situated to the south of the city, and farmed by Mr. McGill. The area of these meadows is at present only 16½ imperial acres; but it is less now than formerly, having been contracted for want, as was stated, of a sufficient supply of sewage. Indeed, the opinion given by Mr. Mc Gill, junior, was, that the greater the amount of water applied the better. The Table (p. 146) shows that the population within the area contributing to these meadows, and the amount of fluid available per acre, are, however, very large. On the other hand, the district is but imperfectly provided with water-closets, and the sewage is probably very dilute. The flow is frequently shifted only once a day, though sometimes three or four times, and in the spring, before the first cutting, generally as much as twice. The water is, as a rule, applied the day the grass is removed. The application is continued through the greater part of the winter, excepting where the last crop has been fed off. Perhaps the sewage is unused about six weeks in the year. The land is heavy, and rather steeply inclined. To a few plots on one side of the valley sewage is applied by gravitation, through a pipe carried across from a higher level of the natural flow on the opposite side.

The herbage contains no clover; and is, in fact, very soon brought down to a very simple character. It contains much couch, and also in some parts a good deal of crow-foot. When the plots are well managed four or five cuttings are obtained during the season. The crops of 1862 were sold at sums varying from 13*l.* to 38*l.* 5*s.* per imperial acre; the difference depending much upon the amount of sewage, the character of the land, the

aspect, and the previous management of the cuttings, all of which affect the amount and character of the produce; but the convenience of position for cartage, proximity to other plots held by the purchaser, and other incidental circumstances, also sometimes affect the rates given for individual plots considerably.

Mr. McGill was of opinion that very much depended upon the quantity and strength of the sewage applied, and stated that portions of the land which had been irrigated by comparatively strong sewage were much more productive than others irrigated by almost pure water.

5. *Rose Bank, Broughton Road.*

These meadows, under the management of Mr. William Reid, comprise a little more than six imperial acres, and have been under irrigation about 30 years. They are watered about 11 months in the year, at a cost of two shillings per week, given to a labourer who does the work of application at his meal-times and in over-time. The runs are, however, cleaned out in the winter by extra labour, paid for by the sale of the refuse, which commands about 2*s.* 6*d.* per ton. As the table shows, the quantity of sewage available is enormous, being about 100,000 tons per acre per annum. Mr. Reid considered that quantity of water was a very important point, but that his supply was sufficient for considerably more land. He had not any more, however, at a convenient level, and did not consider that it would pay to be at any expense in raising the sewage. The irrigation is continued throughout the greater part of the winter as well as in the summer, and on Sundays as well as on other days. The water is applied to the same plot for three or four consecutive days, and the land gets, on the average, two such dressings for each cutting. It is considered better not to apply the sewage immediately after cutting, but to wait a few days until the grass has begun to shoot. The water does not run off the land clear. Four or five cuttings are obtained annually. The plots are from one-quarter to half an acre. each, and they let at rates which amount to from 25*l.* to 30*l.* per imperial acre.

Mr. Reid's supply of sewage being so abundant, and having garden ground lying conveniently for its application, he occasionally applies it to about two acres; but he stated that he would go to very little expense in arrangements for the application of such small quantities as could be so used. The garden crops for which the sewage was found to be the most useful are turnips, cabbages, and onions.

6. *Quarry Holes.*

The Quarry Holes meadows, farmed by Mr. Thomas Skirving, comprise only about eight imperial acres, and the amount of sewage available per acre is very large, being about 65,000 tons per annum. The whole is in permanent meadow. The sewage is applied day and night, and on Sundays, the whole year round, excepting during very hard frost. A plot of an acre, more or less, receives the supply for about two days at a time, and gets three such dressings between the cuttings; but the water is not put on until two or three days after cutting, nor is it considered desirable to apply it when the grass is far advanced. The amount of population contributing to each acre is greater in the case of these meadows than in that of any other in the neighbourhood of Edinburgh, excepting those of Rose Bank, and the amount of water is also very large. There is no doubt that there is very extravagant expenditure of manurial constituents here, as there is indeed in all the other cases; but it must, at the same time, be admitted that it is under these conditions that a greater amount of produce is obtained per acre under the influence of sewage than anywhere else, and perhaps among all the Edinburgh sewage meadows those of the Quarry Holes stand second to none in point of evenness of herbage, and amount and value of produce per acre. The prevailing grasses are rough meadow-grass and common couch.

Sewage and Irrigation at Croydon.

The following particulars were obtained on the spot, partly from Mr. Latham, the engineer to the Croydon Local Board of Health, and partly from Mr. Marriage, junior, son of the gentleman who rents and farms the irrigated meadows.

The population of Croydon contributing to the sewage tanks is about 16,000; and the water contributed to them is estimated at about 40 gallons per head per day without rainfall, and to average, the year round, perhaps 60 gallons per head per day with rainfall. About 300 acres are rented by the Board at 4*l.* per acre without sewage, and sub-let to Mr. Marriage at 5*l.* per acre with sewage. Up to Midsummer 1864, 260 acres had been prepared for irrigation, of which about 250 might be considered as actually under irrigation during the year. It was intended to have 90 to 100 acres constantly under Italian rye-grass, but as yet not so large an area was under that crop.

The plan of irrigation is to let the sewage flow over from 20 to

30 acres for about four days and nights, and to give three such dressings between each cutting. As much of the water as can be recovered for the purpose is redistributed, and in this way a large proportion is always used at least twice, sometimes three, and even four times over, and on the average about two and a half times, by which its utilization and purification are rendered much more complete than otherwise would be the case. According to the figures given above there are about 6250 tons of the dilute sewage with rainfall annually available for each of the 250 acres; but as so much of the water is re-used, the average amount passing over each acre is very much more. There are also annually available for each acre the excretal matters of about 64 individuals of the mixed population of both sexes and all ages.

The land under sewaged Italian rye-grass is estimated to yield at least four cuttings, and from 30 to 35 tons of green produce per acre per annum. The cuttings commence in April, and last to the end of October, and even into November. This grass sells for about 25 shillings per ton in London, and is estimated to realize from 16 to 17 shillings per ton on the land. The sewaged meadow-grass also yields at least four cuttings annually, but it is much less liked than the Italian rye-grass by the London feeders, and is generally sold on the land by the rod, or grazed, and is estimated to yield several pounds less gross money return per acre per annum than the rye-grass.

Mr. Marriage does not apply the sewage in any systematic way to any other crops than permanent meadow and Italian rye-grass, but was about to try it on a small scale to mangolds.

There was a proposition under consideration by the Board to enlarge the area by 100 to 150 acres, which, notwithstanding the rapid increase of the population and of the sewage of the district, will, if carried out, considerably reduce the number of population contributing, and the amount of sewage available, to each acre annually.

About 180 tons of moist solid matter are annually deposited, or intercepted by the strainers, at the tanks, and are sold by the Board at a very low price per ton.

Before the above arrangements for passing the sewage of Croydon over the land were made, the Board were constantly subjected to legal proceedings on account of the pollution of the river Wandle by the discharge of the sewage into it; but now those having the right of the fishing in the river have found it worth while to put down gratings to prevent the fish ascending the drainage outfall from the sewage-irrigated land.

In the following Table are collected together the results of some partial analyses of Croydon sewage, drainage, &c., which have

been kindly communicated by Mr. Latham. The first four analyses are given on the authority of Messrs. Way, Evans, and R. D. Thompson, and the remainder on that of Messrs. Way and Evans alone.

TABLE I.

Results of the Analysis of the Water of the River Wandle, and of the Sewage of Croydon, before and after Irrigation.

	Grains per Gallon.			
	Inorganic Matter.	Organic Matter.	Total Solid Matter.	Ammonia.
Samples collected October, 1861.				
River Wandle above sewage outfall . .	18·56	1·44	20·00	0·18
Do. do. below sewage outfall . .	20·16	2·08	22·24	0·18
Sewage from an independent sewer . .	48·30	52·20	100·50	6·70
Drainage after sewage irrigation . . .	23·40	2·40	25·80	0·21
Samples collected November 16th, 1861.				
Sewage before reaching the tank, 11 a.m.	26·30	12·80	39·10	...
Drainage after sewage irrigation, 12.30 p.m.	21·25	6·50	27·75	...
Ditto ditto 2.30 p.m.	26·30	2·40	28·70	...
Ditto ditto 4.30 p.m.	25·50	3·45	28·95	...
Samples collected November 18th, 1861 (after a sharp frost).				
Drainage after sewage irrigation, 2 p.m.	20·65	2·65	23·30	...
Ditto ditto 4 p.m.	20·95	2·90	23·85	...

The above analyses do not show what proportion of the several constituents existed in suspension and solution respectively; and, of the two samples of sewage, that collected November 16 contained, even before reaching the land, comparatively little solid matter of any kind. So far, however, as can be judged from these few, and little more than initiative results, it would appear that the water was to a considerably greater degree purified by its passage over and through the land than was the case in the Rugby experiments, in which the arrangements did not admit of the fluid being used two or three times over, as with the more extended area at Croydon. The subject of the composition of the drainage-water passing from land liberally sewaged, but under arrangements for the redistribution of the water until it

is as far as practicable both utilized and purified, is, however, one of great importance, still requiring careful investigation.

In the third report of the Sewage Commissioners they say, that as the result of their labours, extending over eight years, they have confidence in submitting the following conclusions :—

1. The right way to dispose of town sewage is to apply it continuously to land, and it is only by such application that the pollution of rivers can be avoided.
2. The financial results of a continuous application of sewage to land differ under different local circumstances; first, because in some places irrigation can be effected by gravity, while in other places more or less pumping must be employed; secondly, because heavy soils (which in given localities may alone be available for the purpose) are less fit than light soils for continuous irrigation by sewage.
3. Where local circumstances are favourable, and undue expenditure is avoided, towns may derive profit, more or less considerable, from applying their sewage in agriculture. Under opposite circumstances, there may not be a balance of profit; but even in such cases a rate in aid, required to cover any loss, needs not be of large amount.

In their experiments in the first year, three portions of land, of about five acres, were operated upon, and each of these lands was divided into four plots, to be treated respectively as follows :—

Plot 1 to be unsewaged.

Plot 2 to be irrigated with sewage at the rate of 3000 tons per acre per annum.

Plot 3 to be irrigated at the rate of 6000 tons per acre per annum.

Plot 4 to be sewaged at the rate of 9000 tons per acre per annum.

We have endeavoured to make an abstract of the results arrived at, but we find this so unsatisfactory, where we wish to be very clear, that we prefer giving the language and figures of the Commissioners themselves.

1. *Quantities of Sewage applied, and of Green Produce obtained.*

In the first season (1861) the application of sewage did not commence until March in the one field, and April in the other; but, as it was considered that any scheme for the general application of town sewage to agricultural purposes must of necessity be based on the fact of a daily supply the year round, which must be dealt with in winter when of comparatively little value, as well as in summer when of more, the amounts of 3000, 6000,

and 9000 tons, respectively, were, in the second and third seasons, distributed over the entire year, and the quantities supplied from November 1st of one year to October 31st of the next, were taken as those to which the increase of crop was due.

The detailed records relating to the application of the sewage are given for reference in Tables I. and II., pp. 81-89, Appendix No. 1. Of these, Table I., which now follows, is a convenient summary.

TABLE I.

Quantities of Sewage applied per Acre, on each Plot, in each Month, in each of the Three Seasons.

	Sewage per Acre.					
	Five-Acre Field.			Ten-Acre Field (half).		
	Plot 2.	Plot 3.	Plot 4.	Plot 2.	Plot 3.	Plot 4.
1st Season, 1861 : March—October, inclusive.						
	Tons.	Tons.	Tons.	Tons.	Tons.	Tons.
March	632·1	1045·1	1444·2	...	...	...
April	279·9	666·4	117·70	563·0	1145·9	1376·9
May	75·8	96·5	97·7	18·3	64·1	118·8
June	78·8	223·3	577·2	...	...	392·3
July	531·7	430·2	654·1	512·0	392·2	905·7
August	130·6	580·2	787·3	225·9	316·3	595·1
September	143·1	703·3	614·7	34·0	517·7	381·8
October	201·7	678·2	800·7	34·0	367·7	455·8
Totals	2073·7	4423·2	6152·9	1387·2	2803·9	4226·4
Rate per annum	3110·4	6634·8	9229·1	2378·1	4806·7	7245·4
2nd Season, 1862 : November, 1861—October, 1862, inclusive.						
November, 1861	313·1	499·8	745·0	116·3	341·5	451·4
December „	126·6	429·8	527·6	71·5	143·5	277·3
January, 1862	323·0	457·6	583·3	77·4	159·2	235·7
February „	169·2	575·0	751·6	227·5	187·2	330·1
March „	235·4	455·8	478·2	109·9	374·0	524·7
April „	211·8	503·0	720·1	508·5	903·5	876·3
May „	281·8	581·4	763·0	289·6	425·1	1201·5
June „	77·1	164·7	292·7	173·0	327·0	410·0
July „	580·1	840·4	1323·7	595·5	1255·9	2017·0
August „	309·1	476·9	1442·0	397·5	1090·8	1385·6
September „	79·4	623·6	628·6	177·6	396·3	776·9
October „	285·2	386·5	730·9	255·2	485·5	517·8
Totals	2991·8	5994·5	8986·7	2999·5	5999·5	9004·3

TABLE I.—*continued.*

Quantities of Sewage applied per Acre, on each Plot, in each Month, in each of the Three Seasons.

—	Sewage per Acre.					
	Five-Acre Field.			Ten-Acre Field (half).		
	Plot 2.	Plot 3.	Plot 4.	Plot 2.	Plot 3.	Plot 4.
3rd Season, 1863; November, 1862—October, 1863, inclusive.						
November, 1862. .	201·9	513·0	806·8	288·2	597·6	771·3
December ,, . .	114·2	315·2	500·1	151·6	625·5	894·6
January, 1863 . .	351·2	489·3	580·2	493·6	436·0	849·3
February ,, . .	194·6	550·6	655·4	200·9	550·9	1013·6
March ,, . .	482·7	774·4	1375·8	203·9	390·8	397·0
April ,, . .	284·2	550·9	640·5	203·9	395·8	592·5
May ,, . .	90·4	579·3	555·3	39·8	582·9	742·3
June ,, . .	896·6	540·9	462·5	385·4	974·8	949·1
July ,, . .	100·9	426·4	980·6	492·4	344·8	779·6
August ,, . .	...	409·5	964·2	150·4	...	717·0
September ,, . .	275·1	617·3	660·3	...	640·9	495·1
October ,, . .	57·1	232·8	819·0	391·3	459·8	797·1
Totals . . .	2998·9	5999·6	9000·7	3001·0	5999·8	8998·5

Summary. 1861, 1862, and 1863.

1st Season; to Oct. 31st, 1861 . .	2073·7	4423·2	6152·9	1387·2	2803·9	4226·4
2nd Season; to Oct. 31st, 1862 . .	2991·8	5994·5	8986·7	2999·5	5999·5	9004·3
3rd Season; to Oct. 31st, 1863 . .	2998·9	5999·6	9000·7	3001·0	5999·8	8998·5
Totals . . .	8064·4	16417·3	24140·3	7387·7	14803·2	22229·2

It is seen that when calculated over the entire season the supply of sewage was in each case very nearly at the rate intended, but that it varied considerably from month to month. Regularity in this respect was, indeed, sought to be attained within certain limits, but it was necessarily subject to various controlling circumstances. Thus, the sewage was, as a rule, applied on the same plot for an entire day at a time, in order the better to secure its even distribution over the whole, and the rate of flow, and consequently the day's supply, varied considerably. Then, again,

throughout the summer months the stage of growth of the crop much influenced the time of application, which was regulated so as to ensure, as far as possible, the beneficial action of the total quantity applied in each case. Occasionally, too, the supply was entirely stopped, owing to derangements in the machinery, a matter over which there was unfortunately no control.

The amount of green grass obtained from the respective plots, in each of the three seasons, is shown in Tables II. and III.; Table II. giving the amounts obtained in each separate month, and Table III. those in each successive crop. For further details, *see* Tables III. and IV.

Table II. shows that the crops obtained before the end of May were very much larger in the second and third seasons than in the first season, in which case no sewage had been applied during the winter months. The much greater luxuriance of growth in the early season was, indeed, remarkable after the winter applications; and the crops were invariably in the most forward condition where the larger quantities of sewage had been applied. There is, of course, a great advantage in getting an early cut of green food, and a given weight will be worth more quite early in the season than some weeks later. Still, it is not to be supposed that the same amount of increase of produce will be obtained for a given amount of sewage applied during winter, as during the periods of active growth.

It is also to be observed that the crops obtained late in the season, in September and afterwards for example, were always considerably heavier with sewage than without it, heavier with 6000 tons than with 3000, and generally heavier with 9000 than with 6000.

Thus, not only was the total amount of produce obtainable per acre very much increased by the application of sewage, but the period during which an abundance of green food was available was extended considerably, both at the beginning and the end of the season, and it was the more so the larger the quantity of sewage applied, almost up to the highest amount adopted in the experiments, namely, 9000 tons per acre.

Table III. shows that in only one instance, that of the ten-acre field in the wet and cold season of 1862, was there any third cut at all without sewage, whilst, with sewage, four or more cuttings were always obtained, and the later crops were pretty uniformly
t he larger, the larger the quantity of sewage applied.

TABLE II.

Amount of Green Grass obtained during each separate Month.

—	Green Grass per Acre.															
	Five-acre Field.								Ten-acre Field (half).							
	Without Sewage.	With Sewage.							Without Sewage.	With Sewage.						
	Plot 1.	Plot 2.			Plot 3.			Plot 4.	Plot 1.	Plot 2.			Plot 3.			Plot 4.
	tons.	tons.	cwts.	grs.	tons.	cwts.	grs.	tons.	cwts.	grs.	tons.	cwts.	grs.	tons.	cwts.	grs.	tons.	cwts.	grs.	lbs.
First Season, 1861.																
May	–	–	–	–	–	–	–	–	1	9	3	14	–	–	–	–	0	14	0	20	1	4	0	10	2	5	0	0
June	3	2	3	27	4	17	0	14	7	19	1	23	8	14	3	8	4	10	1	1	4	11	2	8	5	4	1	7	8	16	1	7
July	3	1	0	8	2	8	0	15	4	6	0	26	6	14	0	13	0	8	1	18	5	5	1	2	5	8	0	19	1	16	3	24
Aug.	–	–	–	–	3	16	2	23	4	13	2	8	5	19	2	24	1	6	3	9	0	10	2	26	4	12	1	1	5	4	2	7
Sept.	2	2	2	8	1	3	0	12	6	5	1	7	5	0	0	5	2	3	2	7	0	11	0	13	1	15	0	3	4	16	2	0
Oct.	0	19	0	18	2	11	3	0	0	8	0	24	0	16	0	23	0	9	0	8	3	19	1	15	4	0	3	7	3	6	0	2
Nov.	–	–	–	–	–	–	–	–	3	9	1	6	4	2	0	5	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
Dec.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	0	4	0	2	0	7	3	21	0	8	2	0
Totals	9	5	3	5	14	16	3	8	27	1	0	10	32	16	3	8	8	18	0	15	15	16	3	2	22	15	2	12	26	13	3	12
Second Season, 1862.																
May	–	–	–	–	0	19	1	19	9	15	3	9	8	7	3	6	0	17	1	16	1	14	0	5	11	13	2	7	8	14	0	21
June	0	8	1	26	5	10	0	10	5	16	0	26	5	15	1	15	7	10	2	11	15	0	0	3	2	7	2	20	1	15	1	7
July	3	16	0	23	8	2	3	3	–	–	–	–	4	19	1	19	2	11	2	0	0	8	2	24	6	9	3	6	8	16	1	2
Aug.	2	8	2	10	4	16	2	16	9	13	0	25	2	0	2	24	0	11	3	0	6	12	1	3	–	–	–	–	2	15	3	8
Sept.	–	–	–	–	4	0	1	10	6	12	2	10	9	15	0	0	3	8	0	17	0	16	0	8	9	16	1	22	6	2	2	12
Oct.	1	10	0	7	4	8	3	16	2	13	1	5	1	11	1	14	–	–	–	–	3	0	0	5	1	14	3	15	3	8	0	26
Nov.	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1	10	3	9	–	–	–	–	–	–	–	–	–	–	–	–
Totals	8	3	1	10	27	18	0	18	34	10	0	19	32	9	2	22	16	10	0	25	27	11	0	20	32	2	1	14	31	12	1	20
Third Season, 1863.																
April	–	–	–	–	–	–	–	–	–	–	–	–	3	16	3	12	–	–	–	–	–	–	–	–	–	–	–	–	3	14	3	0
May	–	–	–	–	4	9	1	25	12	4	3	18	6	0	0	15	–	–	–	–	–	–	–	–	9	0	0	24	4	7	2	27
June	–	–	–	–	6	4	3	3	3	9	2	20	10	13	2	0	3	7	3	25	13	1	3	23	5	16	0	22	11	13	2	21
July	3	18	3	14	6	7	3	9	5	17	2	2	–	–	–	–	2	19	3	27	5	13	0	6	4	15	0	13	0	9	3	12
Aug.	–	–	–	–	–	–	–	–	4	2	3	5	7	15	3	16	–	–	–	–	–	–	–	–	5	14	3	0	7	16	2	14
Sept.	0	19	3	27	2	7	1	27	6	12	0	23	7	14	0	2	1	12	3	23	6	1	0	2	1	5	1	12	0	12	3	0
Oct.	–	–	–	–	2	12	1	15	2	5	3	5	0	14	1	20	–	–	–	–	–	–	–	–	3	9	3	20	5	12	2	3
Nov.	–	–	–	–	0	3	0	16	0	5	2	10	0	5	2	24	–	–	–	–	0	9	1	6	0	10	0	5	0	11	2	0
Totals	4	18	3	13	22	5	0	11	34	18	1	27	37	0	2	5	8	0	3	19	25	5	1	8	30	11	2	12	34	19	1	21

TABLE III.

Amounts of Green Grass obtained in each successive Crop.

—	Green Grass per Acre.															
	Five-acre Field.								Ten-acre Field (half).							
	Without Sewage.	With Sewage.							Without Sewage.	With Sewage.						
	Plot 1.	Plot 2.			Plot 3.			Plot 4.	Plot 1.	Plot 2.			Plot 3.			Plot 4.
	tons. cwts. grs. lbs.	*tons. cwts. grs. lbs.*			*tons. cwts. grs. lbs.*			*tons. cwts. grs. lbs.*	*tons. cwts. grs. lbs.*	*tons. cwts. grs. lbs.*			*tons. cwts. grs. lbs.*			*tons. cwts. grs. lbs.*
First Season, 1861.																
1st Crop .	6 4 0 7	7 5 1 1			10 7 0 24			13 5 1 22	4 18 2 19	9 18 3 12			11 5 3 2			11 1 1 4
2nd Crop .	3 1 2 26	4 3 1 25			7 8 1 0			9 15 0 11	3 19 1 24	2 11 0 0			5 18 2 17			7 1 3 6
3rd Crop .	– – – –	3 4 0 11			5 16 1 8			5 14 0 26	– – – –	3 2 3 16			5 3 1 0			8 2 2 2
4th Crop .	– – – –	0 3 3 27			3 9 1 6			4 2 0 5	– – – –	0 4 0 2			0 7 3 21			0 8 2 0
Totals	9 5 3 5	14 16 3 8			27 1 0 10			32 16 3 8	8 18 0 15	15 16 3 2			22 15 2 12			26 13 3 12
Second Season, 1862.																
1st Crop .	6 13 1 3	14 12 1 4			15 12 0 7			14 3 0 21	10 19 1 27	16 14 0 8			14 1 0 27			8 14 0 21
2nd Crop .	1 10 0 7	8 16 3 26			9 12 0 25			7 0 0 15	3 19 3 17	7 0 3 27			6 9 3 6			10 11 2 9
3rd Crop .	– – – –	3 18 1 9			8 1 0 5			9 15 0 0	1 10 3 9	3 7 3 2			9 16 1 22			8 18 1 20
4th Crop .	– – – –	0 10 2 7			1 4 3 10			1 11 1 14	– – – –	0 8 1 11			1 14 3 15			3 2 0 5
5th Crop .	– – – –	– – – –			– – – –			– – – –	– – – –	– – – –			– – – –			0 6 0 21
Totals	8 3 1 10	27 18 0 18			34 10 0 19			32 9 2 22	16 10 0 25	27 11 0 20			32 2 1 14			31 12 1 20
Third Season, 1863.																
1st Crop .	3 18 3 14	10 14 1 0			12 4 3 18			9 16 3 27	6 7 3 24	13 1 3 22			12 9 0 7			8 3 1 27
2nd Crop .	0 19 3 27	6 7 3 9			9 7 0 22			10 13 2 0	1 12 3 23	5 13 0 6			7 2 1 24			11 13 2 21
3rd Crop .	– – – –	4 2 3 24			7 2 3 1			6 18 2 5	– – – –	6 1 0 2			7 0 0 12			8 6 1 26
4th Crop .	– – – –	0 16 3 18			5 18 0 4			8 11 1 13	– – – –	0 9 1 6			3 9 3 20			6 5 1 3
5th Crop .	– – – –	0 3 0 16			0 5 2 10			0 14 1 20	– – – –	– – – –			0 10 0 5			0 11 2 0
6th Crop .	– – – –	– – – –			– – – –			0 5 2 24	– – – –	– – – –			– – – –			– – – –
Totals	4 18 3 13	22 5 0 11			34 18 1 27			37 0 2 5	8 0 3 19	25 5 1 8			30 11 2 12			34 19 1 21
Summary—1861, 1862, and 1863.																
1861. .	9 5 3 5	14 16 3 8			27 1 0 10			32 16 3 8	8 18 0 15	15 16 3 2			22 15 2 12			26 13 3 12
1862. .	8 3 1 10	27 18 0 18			34 10 0 19			32 9 2 22	16 10 0 25	27 11 0 20			32 2 1 14			31 12 1 20
1863. .	4 18 3 13	22 5 0 11			34 18 1 27			37 0 2 5	8 0 3 19	25 5 1 8			30 11 2 12			34 19 1 21
Average .	7 9 1 9	21 13 1 12			32 3 1 0			34 2 1 12	11 3 0 10	22 17 3 1			28 9 3 13			31 1 3 18

ABSTRACT OF TABLE IV.

Total Amounts of Produce, and the Increase for 1000 *Tons of Sewage applied, both reckoned as Green Grass and calculated as Hay.*

SEASONS 1861, 1862, AND 1863.

	Five-acre Field.				Ten-acre Field (half).				Mean of the two Fields.			
	Without Sewage.	With Sewage.			Without Sewage.	With Sewage.			Without Sewage.	With Sewage.		
	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 1.	Plot 2.	Plot 3.	Plot 4.	Plot 1.	Plot 2.	Plot 3.	Plot 4.
Produce per Acre, per Annum, as Green Grass.												
	tons. cwts. qrs. lbs.	*tons. cwts. qrs. lbs.*	*tons. cwts. qrs. lbs.*	*tons. cwts. qrs. lbs.*	*tons. cwts. qrs. lbs.*	*tons. cwts. qrs. lbs.*	*tons. cwts. qrs. lbs.*	*tons. cwts. qrs. lbs.*	*tons. cwts. qrs. lbs.*	*tons. cwts. qrs. lbs.*	*tons. cwts. qrs. lbs.*	*tons. cwts. qrs. lbs.*
Average -	7 9 1 9	21 13 1 12	32 3 1 0	34 2 1 12	11 3 0 10	22 17 3 1	28 9 3 13	31 1 3 18	9 6 0 24	22 5 2 7	30 6 2 6	32 12 0 15
Produce per Acre, per Annum, calculated as Hay.*												
Average -	2 10 2 7	5 5 1 20	6 1 2 15	6 16 0 17	3 11 0 0	4 18 0 18	5 9 1 3	6 2 3 7	3 0 3 4	5 1 3 5	5 15 1 23	6 9 1 26
Increase, reckoned as Green Grass, for each 1000 Tons of Sewage applied.												
Average -	...	5 2 0 27	4 9 1 15	3 7 1 8	...	4 16 0 15	3 15 1 13	2 19 0 22	...	4 19 0 21	4 2 1 14	3 3 1 1
Increase, calculated as Hay, for each 1000 Tons of Sewage applied.												
Average -	...	0 19 3 19	0 13 0 13	0 10 3 27	...	0 12 0 25	0 8 3 7	0 8 0 2	...	0 16 0 8	0 10 3 24	0 9 2 1

* The amount of hay to which the grass is supposed to be equivalent, is calculated by raising the amount of the experimentally determined perfectly dry or solid substance in the grass, in the proportion of from 84 to 100, on the assumption that the hay would contain 84 per cent. of dry substance and 16 per cent. moisture.

"Leaving the question of the amounts of produce obtained during each separate month, or at each successive cutting, Table IV. shows the total amount of produce on each plot, in each of the three seasons, and also the amount of increase for every 1000 tons of sewage applied; and produce and increase are each recorded both as green grass, and calculated as hay. The means of the results obtained in the two fields are also given.

"In the first and third years (1861 and 1863) there was, in both fields, more produce, whether reckoned as green grass or as hay, with each increased amount of sewage applied. In the wet and cold season of 1862, however, although there was considerably more green produce per acre from 6000 tons of sewage than from 3000, yet, owing to its more succulent condition, the amounts with the larger quantity of sewage represented even a few cwts. less of hay. On the other hand, with 9000 tons of sewage, the produce of green grass was, in this wet season, in both fields, less than with 6000 tons, but calculated as hay it was slightly more. In no case, however, is the increase with the larger amounts of sewage in proportion to the increased application. This point is well illustrated in the two lower sections of Table IV., which give, not the produce per acre, but the increase for each 1000 tons of sewage applied, reckoned respectively as green grass and as hay.

"It is obvious that the proportion of the produce to be reckoned as increase due to the sewage applied must depend very much on the yield of the unmanured land with which the produce of the sewaged land is to be compared. It is necessary, therefore, to bear in mind the quality and condition of the land upon which the experiments were made, when estimating and judging of the amounts of increase yielded for a given amount of sewage applied. Both fields were fattening pastures. It may safely be concluded, therefore, that their natural or unmanured produce would be higher than that of the average of such land as would be likely to be devoted to the growth of grass by means of sewage on the large scale. On the other hand, there is no reason to suppose that under the influence of a liberal supply of sewage, the produce would be in a corresponding degree higher on land of high natural yield than on land which, from its suitable physical qualities, might, with sewage, yield heavy crops, but without it very light and poor ones. Then, again, a large proportion of the grasses of a good fattening pasture will yield less produce under the influence of sewage than others associated with them, and it is not until the application has been continued for some years that the more freely growing grasses become so far dominant as to secure the maximum result for a given amount of sewage that soil and season will admit of. For these reasons it seems

probable that the amounts of *increase* obtained for a given amount of sewage, applied in these experiments, are more likely to be below than above those which may be anticipated on the continued application of sewage, over large areas of land, selected, prepared, and properly seeded for the purpose.

"As between the two fields, it should be stated that, to the five-acre field no sewage had been applied during the season preceding the commencement of the experiments; one crop of hay had been taken from it, and it had afterwards been eaten down by sheep. To the ten-acre field, however, sewage had been applied in indefinite quantity for nearly 12 months; two crops of hay had been taken from the land in the previous year, and it had been kept very closely grazed down by stock almost up to the time of commencing the experiment. Thus, though this land of the field was undoubtedly of higher natural quality, and was probably also in a higher condition, so far as the influence of recent manuring was concerned, yet, owing to its herbage being so much more closely grazed down, it was in that respect in a less favourable condition for the first year's crop, and accordingly, in the first season, gave, without sewage, less produce than the other, though in succeeding seasons it gave much more. Indeed, whilst in the five-acre field the produce without sewage diminished from year to year, being even less in the second year than in the first, notwithstanding the much larger amount of rain, it was in the ten-acre field so very much larger in the second year than in the first, and so very much larger in both the second and third years in that field than in the other, that it was thought, until full inquiry had been made, that there must be some error either in the measurement of the land or in the records. None was, however, found; and the difference in the character and composition of the two soils, which subsequent examination showed, satisfactorily accounted for the great difference in their natural yield.

"These few remarks on the character and condition of the land in the two fields will serve as some explanation of the proportionally much greater difference in the amounts of increase over the natural produce from a given amount of sewage, than in the amounts of total produce per acre, where the same amounts of sewage are applied in the different fields or in different seasons. A few comments only need be made on the results themselves as recorded in the Table.

"In the first season the sewage was not applied experimentally until March in the five-acre, and April in the ten-acre field, and hence the amounts of increase of produce yielded had to be reckoned as due to comparatively small quantities of sewage

applied. Taking the average amount of the two fields, the increase obtained for 1000 tons of sewage applied, when reckoned as green grass, was rather more when the two larger than when the smallest quantity of sewage was applied per acre, but reckoned at one uniform condition of dryness as hay, it was slightly less with each increased amount of sewage applied.

"In the wet and cold season of 1862, which was, of course, favourable for the unsewaged land, and by comparison the less appropriate the greater quantity of sewage applied, the amount of increase for 1000 tons of sewage, whether reckoned as green grass or as hay, diminished considerably with each increase of sewage applied per acre. And notwithstanding the amounts of total produce per acre with equal quantities of sewage were not very different in the two fields, the amounts reckoned as increase for 1000 tons of sewage applied were very much less in the ten-acre than in the five-acre field, owing to the much larger produce without sewage in the former.

"In 1863 again, though a much warmer and more genial season for the action of sewage, there was still, though in a much less degree than in 1862, a diminishing proportion of increase for 1000 tons of sewage, the larger the quantity applied per acre. There was also, owing chiefly to the much larger produce without sewage, much less to be reckoned as increase for each 1000 tons of sewage applied in the ten-acre than in the five-acre field.

"It is worthy of remark, that although the produce per acre without sewage is so much the greater in the ten-acre field than in the other, it is with equal, but especially with the larger amounts of sewage, pretty uniformly the greater in the five-acre field. This result was doubtless partly due to its being better fitted, from its porosity, for sewage irrigation, but partly also to the fact, that whilst it was comparatively flat, allowing the sewage to pass over it more slowly and so to be better absorbed, the ten-acre field was in high ridges, and steeply inclined, rendering it difficult to prevent the water running over it too quickly. This point will be illustrated further on by reference to the comparative composition of the drainage water from the two fields.

"Taking the average results of the three years, and the two fields, we have, with sewage applied at the rate of 3000 tons per acre per annum a produce per acre of a little over 22¼ tons of green grass, equal rather more than 5 tons of hay; with 6000 tons of sewage rather more than 30¼ tons of green grass, equal rather more than 5¾ tons of hay; and with 9000 tons of sewage

rather more than 32½ tons of green grass, equal about 6½ tons of hay.

"The largest quantities of produce reached were those obtained with the largest quantities of sewage (9000 tons per acre per annum), and in the third year of the experiments, amounting in the five-acre field to 37 tons of green grass, equal rather more than 7 tons of hay, and in the ten-acre field to nearly 35 tons of green grass, equal nearly 6 tons 13 cwts. of hay.

"The average increase of green grass over the natural produce for 1000 tons of sewage applied was, with 3000 tons of sewage per acre nearly 5 tons, with 6000 tons of sewage rather more than 4 tons, and with 9000 tons not quite 3¼ tons. Reckoned as hay, the average increase for 1000 tons of sewage was, with 3000 tons of sewage per acre 16 cwts., with 6000 tons nearly 11 cwts., and with 9000 tons 9½ cwts. As, however, these average results relating to increase include those of the ten-acre field, where, owing to the very high natural produce, the amount reckoned as increase due to sewage was comparatively small, it is probable that results equal at any rate to those of the five-acre field may be expected in the average of cases elsewhere; and where, as may frequently happen, a soil which yields a very small natural produce, may, nevertheless, owing to its physical qualities, be well adapted for the application of sewage and give large amounts of produce per acre under its influence, the amounts of increase for a given amount of sewage applied may be even considerably higher than those obtained in the five-acre field.

"The general result is, that there was much more total produce per acre with 6000 tons of sewage than with 3000, and more still with 9000; but that the increase for a given amount of sewage applied was less with 9000 tons than with 6000, and less with 6000 than with 3000.

"The increase in the amount of produce with each increase in the quantity of sewage applied appears proportionally greater when reckoned as green grass than as hay. This is due to the much greater succulence, and, therefore, less proportion of dry substance in the more highly sewaged and heavier crops. The question arises, whether, with a less proportion of dry substance in the sewaged grass, a given weight of that dry substance will have a greater or a less value as food for stock than an equal weight from the less succulent unsewaged grass?

II. *Experiments with Italian Rye-grass.*

"In April 1863 arrangements were made with Mr. Campbell for gauging the sewage applied, and weighing and sampling the produce obtained, in a field of Italian rye-grass, and also for trying the feeding qualities of the grass. From the field in question, a crop of tares, which had been manured with farm-yard dung, had been carried off in the spring of 1862. The land was then cleaned, again manured with stable and farm-yard dung, and sown down with rye-grass in September (1862); and at the time of commencing the experiment in the following Spring there was a promising and tolerably even crop.

"Three plots of about an acre each were set apart; plot 1 to be unsewaged; plot 2 to receive sewage at the rate of 3000; and plot 3 at the rate of 6000 tons per acre per annum. So meagre was the flow, however, that up to the end of October (1863) only 787 tons had been applied to plot 2, and 1522½ tons to plot 3, instead of 1512 and 3057 tons respectively, that were required according to the rates intended, reckoning from the date of the first application in the Spring.

"The particulars of the amounts of sewage applied, and of the amounts of produce and increase obtained, reckoned both as green grass and in the condition of dryness of hay, are given in Table V. Further details will be found in Table V.

TABLE V.

Amounts of Sewage applied, and of Produce and Increase obtained, in Experiments on Italian Rye-grass.

SEASON 1863.

	Without Sewage.	With Sewage.	
	Plot 1.	Plot 2.	Plot 3.
	Sewage applied per Acre.		
		Tons.	*Tons.*
April - - -	...	...	48·0
May - - -	...	152·1	257·6
June - - -	...	178·0	354·7
July - - -	...	218·1	403·1
August - -	...	120·8	163·4
September - -	...	60·1	219·9
October - -	...	58·1	75·9
Total - -	...	787·2	1522·6

TABLE V.—(*continued.*)

Amounts of Sewage applied, and of Produce and Increase obtained, in Experiments on Italian Rye-grass.

SEASON 1863.

	Without Sewage.	With Sewage.	
	Plot 1.	Plot 2.	Plot 3.
Rye-grass obtained per Acre, during each separate Month.			
	Tons cwts. qrs. lbs.	*Tons cwts. qrs. lbs.*	*Tons cwts. qrs. lbs.*
April	3 4 1 21	4 3 1 22	3 15 3 15
May	1 17 2 23	– – – –	1 11 1 7
June	8 18 0 22	7 1 1 27	6 9 3 13
July	– – – –	5 16 3 21	6 10 2 21
August	2 0 1 13	1 14 1 13	3 0 2 10
September	0 9 2 7	0 13 1 6	1 12 0 11
October	0 6 0 9	1 5 3 16	2 3 0 12
	16 16 0 19	20 15 1 21	25 3 2 5
Rye-grass obtained per Acre, in each successive Crop.			
1st Crop	5 2 0 16	4 3 1 22	3 15 3 15
2nd Crop	8 18 0 2	7 1 1 27	5 14 0 3
3rd Crop	2 0 1 13	5 16 3 21	7 7 1 13
4th Crop	0 9 2 7	1 14 1 13	4 2 2 23
5th Crop	0 6 0 9	0 13 1 6	2 0 1 23
6th Crop	– – – –	1 5 3 16	2 3 0 12
	16 16 0 19	20 15 1 21	25 3 2 5
Summary of Produce per Acre.			
Green Grass	16 16 0 19	20 15 1 21	25 3 2 5
Reckoned as Hay*	4 18 3 8	5 5 0 16	5 12 2 11
Increase of Produce per Acre.			
As Green Grass	...	3 19 1 21	8 7 1 14
Reckoned as Hay*	...	0 6 1 8	0 13 3
Increase for each 1000 Tons of Sewage applied.			
As Green Grass	...	5 0 2 25	5 9 3 17
Reckoned as Hay*	...	0 8 0 4	0 9 0 5

* The amount of hay to which the grass is equivalent is calculated by raising the amount of the experimentally determined perfectly dry or solid substance in the grass, in the proportion of from 84 to 100, on the assumption that the hay would contain 84 per cent. of dry substance and 16 per cent. moisture.

"When the experiment with rye-grass was determined upon early in April, the grass was so far forward that it was found necessary to take a first cutting without sewage, before the water-runs could be properly adapted for the separate irrigation of the respective plots, and hence but little sewage was applied before the end of April, and that little only on plot 3. The effect of the sewage was, therefore, as the second and third divisions of the Table show, to increase the produce chiefly during the later months and later crops of the season, and it did so very much in proportion to the amounts applied.

"The total produce per acre was, without sewage (though otherwise pretty well manured), rather more than 16¾ tons, with 787 tons of sewage rather more than 20¾ tons, and with 1522½ tons of sewage nearly 25¼ tons of green grass; or, reckoned at a uniform condition of dryness as hay, the amounts were equivalent to 4 tons 18¾ cwts., 5 tons 5¼ cwts., and 5 tons 12½ cwts. respectively. The increase of produce per acre was, therefore, nearly 4 tons of green grass due to the smaller, and about 8 tons 7½ cwts. due to the larger application of sewage; though the increase in real dry substance represented only 6¼ cwts. and 13¾ cwts. of hay respectively.

"The increase reckoned for 1000 tons of sewage in each case was, with the smaller quantity applied, 5 tons 0¾ cwts., and with the larger quantity, nearly 5 tons 10 cwts. of green grass; but the increase of real dry substance represented only 8 cwts. and 9 cwts. of hay respectively. The increase in real dry or solid substance was, therefore, very small; but it will be seen further on that, at any rate in the case of the meadow-grass (and it is probably the same with the rye-grass), a given amount of the dry substance of the sewaged produce was more productive of milk, and even slightly more of increase, than an equal amount of the dry substance of the unsewaged.

"The general result is, that there was as much or more increase of green produce for 1000 tons of sewage with the rye-grass than in most of the cases in the same season with the meadow-grass, where so very much larger quantities of sewage were applied, though the increase of dry substance reckoned as hay was generally the higher with the meadow-grass. That is to say, the comparatively large amounts of sewage applied to the meadow-grass gave, on the average, a larger amount of increase in dry or solid substance, for a given quantity of sewage, than the much smaller amounts applied to the rye-grass. It is also to be observed that there was a larger amount of increase, both of green grass and of dry substance reckoned as hay, for a given quantity of sewage on plot 3 with the larger, than on plot 2 with the smaller amount

applied to the rye-grass. The facts point to the conclusion that, for the season in question, the larger quantity applied was below that required to yield the maximum increase for a given amount of sewage. It is obvious, however, that it may be advantageous even to pass this point; for, within certain limits, it will be economical to reduce the area and cost of distribution at the expense of a certain sacrifice of sewage.

"It is to be regretted that the plant of rye-grass was so much injured by frost during the winter of 1863-4 (and it was the more so where the sewage had been the most liberally applied), that it was necessary to plough it up, otherwise the experiment would have been continued through the season of 1864. Instead of this, barley was sown over the three plots without any further manure, and it was obvious to the eye during growth that the crop was much heavier where sewage had been applied to the rye-grass than where it had not, and heavier where the larger than where the smaller quantity had been applied.

III. *Experiments with Fattening Oxen.*

"We may venture to summarize these, by observing that the Commissioners say that a very much higher money value was obtained both from an acre of land, and from a given amount of sewage, when the sewaged grass was employed for the production of milk instead of meat. They mention, however, that at Croydon, although on land more liberally sewaged than at Rugby, satisfactory results have been obtained with fattening stock fed on the land, to which they are turned on when the grass has got a sufficient head, and the application of sewage has been stopped, and where the cattle remain until the grass is closely eaten down.

IV. *Experiments with Milking Cows.*

"By the kindness of Mr. Campbell experiments were made with his cows each year, 1861, 1862, and 1863, on the milk-yielding qualities of the grass.

"In 1861, 12 of Mr. Campbell's cows were carefully selected and set apart to be fed on grass alone, 2 on unsewaged and 10 on sewaged grass, and the experiment was so conducted over a period of 16 weeks. It was afterwards continued for 4 weeks longer, with an allowance of oilcake as well as grass.

"In 1862, 3 cows were selected to receive oilcake and unsewaged, and 12 oilcake and sewaged grass, and the experiment was continued for 24 weeks.

"In 1863, 20 recently calved cows were selected, 5 to be fed on unsewaged meadow grass, 10 on sewaged meadow grass, and 5 on Italian rye grass. The design was to give each lot grass alone for the first 12 weeks, and afterwards a certain amount of oilcake in addition.

"Reviewing the results of the experiments in which sewaged was tried against unsewaged meadow grass, it is observable that, excepting in the first season (1861), the cows required more both per head per day, and per 1000 lbs. live weight per week, of the fresh or green sewaged than of the unsewaged grass; yet the yield of milk, both per head and per 1000 lbs. live weight, was, without exception, the greater with the unsewaged grass. The increase in live weight was also somewhat the greater on the unsewaged grass in 1861 and 1862, but the contrary was the case in 1863.

"Reckoned in the fresh or green state in which it was cut and carted, there was in fact, in every case but one (and then the quantities were equal), considerably less of the unsewaged than of the sewaged grass required to be consumed for the production of one gallon of milk. It should be remarked, however, that the unsewaged grass was generally cut in a much riper and less succulent condition, and therefore contained a considerably higher per-centage of dry or solid substance than the sewaged. It may be also here mentioned that in 1863 the cows having professedly unsewaged meadow grass, in default of a sufficient supply of it, had necessarily for a considerable part of each of the periods of 12 weeks unsewaged rye-grass.

"Weight for weight, in the fresh or green state in which the grass was cut, weighed, and given to the cows, the unsewaged grass has, therefore, proved to be far more productive than the sewaged. But when the comparison is made, not between the amounts of grass reckoned in the fresh state, but between the amounts of dry or solid matter which the different descriptions of grass supplied, the result is that, in only one instance was there more, and in the others there was either an equal amount or even less of dry or solid substance of sewaged than of unsewaged grass required for the production of a given amount of milk.

"The general result in regard to these points was, then, that in both milk and increase, but especially milk, a given weight of animal was more productive when fed on unsewaged than on sewaged grass, and that a given weight of fresh unsewaged grass was more productive than an equal weight of fresh sewaged grass; but that a given weight of dry or solid substance supplied in sewaged grass was more productive than an equal weight supplied in unsewaged.

"A careful consideration of the results leads to the conclusion that there was some considerable variation in the quality of the grass in the three different seasons. It was obviously very inferior in the wet and cold season of 1862. There is also evidence of a considerably diminished productiveness of a given weight both of green sewaged grass and of the dry substance of sewaged grass towards the end of the season; though part of the falling off which the figures show is doubtless attributable to the changing condition of the cows themselves as the season advanced.

"The experiments do not afford the means of strictly comparing the productive qualities of rye grass with those of meadow grass, or of sewaged with those of unsewaged rye grass. Thus, as already alluded to, the cows professedly fed on unsewaged meadow grass in 1863 had, during a considerable part of the experimental period, unsewaged rye grass; whilst those fed on rye grass had indiscriminately the unsewaged and the sewaged. The indication is, however, that somewhat more of the dry substance of the sewaged rye grass than of the sewaged meadow grass was required to produce a given result; though the difference is less during the later than the earlier period of the season. It is probable, indeed, that sewaged Italian rye grass deteriorates less towards the end of the season than sewaged meadow grass.

"It remains to indicate, approximately, the increased yield of saleable produce, and the money value of that produce, from an acre of land, and from 1000 tons of sewage, according to season, and to the amount of sewage applied.

"The last ten columns of Table VII. of the Report refer to these points. In explanation of the figures there given it should be stated, that the estimates of the amount, and value, of the milk yielded per acre, are, in the case of each plot, based upon the total amounts of grass obtained per acre throughout the season, and upon the average rate of consumption and yield of milk during each separate period, on unsewaged grass in the case of plot 1, and on the mixed sewaged grass in that of plots 2, 3, and 4; and the estimates are framed so as to show, so far as practicable, the amount and value, both inclusive and exclusive of oil-cake when it was given, as will be better understood by reference to the columns in the Table, and the foot note relating thereto.

"It is obvious that such estimates can only be approximations to the truth. But such they are, and considered as such only, they are little likely to mislead any acquainted with practical agriculture, and with the limits within which such calculations are not of general application.

"Referring first to the experiments with meadow grass, the result (excluding the case of 1862, when the unsewaged crop in

the ten-acre field was so very large) was, that the produce of an acre with sewage was competent to feed one cow for from 19 to 23 weeks, varying according to the season, or whether the grass were consumed alone or with oil-cake in addition. The same area was, with the aid of 3000 tons of sewage, rendered capable of providing keep for two to two and a half cows for the same period of time; or, as represented in the Table, for one cow from two to two and a half times as long, with 6000 tons of sewage for three to three and a half times as long, and with 9000 tons from three and a half to four times as long.

"Represented in quantity of milk, in 1861, when the sewage was not applied until the Spring, the produce per acre was, without sewage, 321½ gallons, and with the different amounts of sewage 570¾, 820½, and 961¼ gallons respectively. Reckoned according to the rate of consumption of grass and of the yield of milk during the first 12 weeks, or most favourable period, of the grass season of 1863, when, as in 1861, the grass was consumed alone, but unlike 1861 the sewage had been applied throughout the winter months, and when the cows being mostly newly calved were also in their most favourable condition, the estimated yield of milk reckoned upon the total produce of grass per acre was, without sewage 402 gallons, and with the different amounts of sewage 1019, 1404¾, and 1544 gallons respectively; or, so far as the sewaged plots were concerned, from one-half to two-thirds more per acre than in 1861, reckoned according to the rates of consumption and yield of milk over the whole of that season.

"With the aid of the large quantities of the oil-cake stated in the Table, the yield of milk per acre in 1862, when the season was very favourable for the unsewaged but comparatively unfavourable for the sewaged land, was, without sewage 666½ gallons, and with the different amounts of sewage 920½, 1072¾, and 1056 gallons; and, according to the rates of consumption and yield of milk when oil-cake was given during the latter half of the season of 1863, the yield of milk per acre calculated upon the total produce of grass throughout the season in each case was, without sewage 444¼ gallons, and with the different amounts of sewage 780, 1075, and 1181½ gallons respectively.

"The general result is, that, on the sewaged plots, the yield of milk was at a less rate per acre with oil-cake during the latter or inferior part of the season of 1863, than without it during the earlier or more favourable portion of the same season: but it was at much the same rates per acre during the latter or inferior part of the comparatively favourable season of 1863, as during the entire period of the unfavourable season of 1862. Lastly, on this point, the yield of milk per acre over the entire season of 1863,

half without and half with oil-cake, was higher than that of 1862 with oil-cake throughout, and considerably so on the more highly sewaged plots.

"So far as may be judged from the limited experience which these results record, it would appear probable that with an average supply of about 5000 tons of sewage per acre per annum to meadow land, and with cows taken indiscriminately at various periods after calving, an average of not less than 1000 gallons of milk per acre might be expected; or more than this when the cows are taken at their best, and the season and other circumstances are more than usually favourable."

Works of irrigation, either by water only or by sewage, are carried out in different modes. After the water is delivered on the ground, it may be allowed to lay for some time, and there can be no doubt that this system is the one most likely to produce noxious results; it is more extensively carried out in very warm countries than it is in our temperate climate; often very injudiciously.

There is no doubt that the best, or safest, mode of irrigation is that where the water is kept in constant motion, and where thus used, it will probably not be more injurious to health than are the waters of large sluggish rivers, at least generally.

When the ground to be irrigated has any considerable slope, that is in side-lying ground, the water or sewage is usually delivered from the main carrier at different contour levels, at which the gutters are cut, and to which it is delivered consecutively; it is taken first to the head of the ground, or highest level, and runs into the first level gutter. The gutters are generally more or less regular curves following the contour level, or at least having only a very slight fall; but sometimes the different level gutters are cut in a zigzag form. This form is adopted in order to keep an equal level across the ridges and furrows, which a former state of constant ploughing has left irregular on the slopes of the declivities, so that the trenches may be of no greater depths or dimensions in the ridges than in the adjacent furrows; and that each level gutter may, when charged with water, discharge it equally over the lowest edge of the trench, from one end to the other at one and the same time.

The size of the different level gutters must depend upon various circumstances, such as the area of a field, the distance of the gutters apart, and also sometimes upon whether it is intended to make use of any of them for the purpose of carrying the sewage into any adjoining field or meadow, regularly or at intervals.

On this subject it is well to remember that where a field is well drained we may, at least so it is supposed at present, deliver almost any quantity of sewage, particularly at certain times of the year; this may sometimes afford some facilities for the occasional irrigation of other grounds, where it might be advantageous if applied only at particular times. We do not, however, mean that the vegetation of any particular meadow, for instance, should have its supply suddenly stopped entirely, because we believe that this would be injurious in cases where the irrigation is usually constant.

The liquid of irrigation having passed into the first or highest level gutter flows over the ground below, and into the next lower level gutter, and so on down the declivity of the field. It is said, however, that by this system the grounds at the higher levels of the field get the best of the sewage.

The gutters above referred to, at the end where they receive the sewage from the main carrier, which should generally be covered, are often made about eight inches wide at top, and six inches deep; sharp at the bottom and gradually tapering towards their ends; when they are no more than six inches wide and four inches deep, they are cut across the slope of the field at a distance of ten or fifteen yards apart.

The sod taken from a gutter of this sort is of wedge-like shape; one of the largest, at the end adjoining the main carriers, is kept and used as a stop, and is placed either in the collateral level, or the carrier, as occasion may require; these stops dam the sewage back and make it flow over the ground in a uniform stream. The remaining sods are usually broken up, and spread over any hollow places to obtain the most regular or level surface possible. No part of any of the excavated sod is left above the ground, as this would obstruct the mowing. It is to be remembered that any hollows in a field where sewage may accumulate will be very detrimental, not only because it stops the flow of the sewage, but because it does harm in itself by lying there, and this more particularly if the sewage is strong and fresh.

We have explained above how the various gutters distribute the liquid over a field on a hill-side, and how where water is wanted for an adjacent field one of the gutters is made a collecting gutter, and by a proper management of the stops the contents are poured into any field where they are wanted. Where there is not town sewage to dispose of in this manner, liquid manure is often prepared by thorough dilution in tanks with guano and farm-yard refuse, and this is allowed gradually to flow into the carrier, from which it is distributed into the gutters.

In a somewhat different system of distribution, and which is

more suitable when the inclination of the ground is slight, we have first, the main carrier, which brings the liquid to be distributed, and which is generally laid across the ground in the direction of its least fall, and the trenches or troughs which branch from the main carriers, and carry sewage or water in the direction of the greatest fall. The stops consist of one, two, or more stakes, driven down in the middle of the main carriers or trenches, to obstruct the course of the water, and keep it high enough to flow through the sluices, which are small openings made in the sides of the trenches at the distance of one or two yards apart, and through which the water passes to irrigate the land. The drains are ditches cut in various directions, and of different dimensions, terminating in one trunk to carry off the water after it has done its work. The more rapid the current, the more numerous should be the stops. The main trunk drain and the main carrier are often more or less parallel, the latter at the lower level, and the former at the highest level of the irrigated grounds; the trenches and drains springing from them are also very often quite or nearly parallel, like the teeth of two rakes brought close together.

The main carrier running along the upper part of the grounds should have the banks of an equal height, and a few inches higher than the general surface; these carriers should be about nine feet wide and two feet deep for an area of about fifteen acres; the smaller trenches are cut from these at nearly right angles. The distance of these apart is about ten or twelve yards; ten yards wide upon the surface may be irrigated by a ditch two feet wide and one deep.

In cold and swampy grounds, the distance between the troughs and drains, which we have already said are more or less parallel, should not exceed four or five yards. The inclination of the ground is often regulated at from 1 in 20 to 1 in 30 for meadows, and the depth of water at about two inches; to a great extent, however, this must be regulated by climate, soil, season, and crops. For the better or more uniform distribution of water in spring, it is not unusual in some places to cut small temporary trenches where they appear to be wanted; but after the watering is over, the sods which had been laid by the side of the trenches are replaced in the trenches, with a view to the coming mowing.

In irrigating from streams or rivers, where the lands slope towards the watercourse, and when therefore it is not possible to irrigate without pumping from the waters just below the grounds, it is necessary to gain a fall by tapping the stream higher up its course, where at least it is possible to do so. For this purpose it is necessary to level from the summits of the

highest grounds to be irrigated to the stream, and then upwards, in order to gain a head; these levels require care, and attention should be given that the stream is tapped at a level which will ensure water when the stream is at a low summer level. Strange as such a statement may appear, many expensive mistakes have occurred through want of attention to these apparently minor matters.

From the level thus selected, the water is conducted at a slight fall, to some level where it may sometimes branch out into several main carriers, to irrigate different levels. Here again some amount of care is required to do this judiciously, and it will generally be found that plans on which numerous levels are shown in figures, as taken from cross sections and contours, are very useful, if not absolutely necessary, in laying down the lines for carriers and trenches. When irrigating from streams by means of carriers, we may sometimes by means of hatches and sluices, dispense with some of the secondary main carriers.

In flat level countries, where any extensive irrigations are to be carried on, and it is desirable to keep the sewage or irrigation water as much as possible in motion, it is a common practice to adopt a ridge and furrow practice in broad bands, the carrier trenches being cut along the summit of the ridge, and the water flowing off on either side down into the furrows.

Catch work meadows may be formed by turning a stream along the side of a hill, and thereby watering the land between a new cut and the original water course, which for a given length is made a main carrier. This is sometimes done by making the main cut level and stopping it at the end, so that when the cut is full, the water runs over the sides and floods the ground.

But as the water would soon cease to run equally for any great length, and would wash out the land in gutters, it is found better to cut small parallel trenches from six to ten yards apart, to catch the water again; each of these being likewise stopped at the end, allows the water to flow over the side, and distributes it until caught by the next trench, and so on over the intermediate beds down to the main drain at the lower level, which may be the drain for carrying the water away to waste, or into another meadow at a lower level still.

To draw the water out of these parallel trenches, and lay the intermediate beds dry, deep narrow drains cross them at right angles, and lead from the main carrier at top, to the main drain at the lower level.

When the lower meadow is to be watered, the ends of the carriers adjoining the cross drains are stopped with turfs on the spot, and the water flows over so much of the ground as it will

well irrigate at a time. When this pitch is to be laid dry, the turfs are taken up, and the water flows off through the drain on to another pitch.

The above is a very inexpensive mode of irrigation, the stream being usually small and manageable, with few, if any hatches, and but little manual labour is required to let on the water and get it off again. Meadows at low levels, comparatively speaking, and floated from rivers, generally require much more system, and also labour, as to letting the water on, but more particularly getting it off-again. It is here often required to throw the land up into high ridges with deep drains between them.

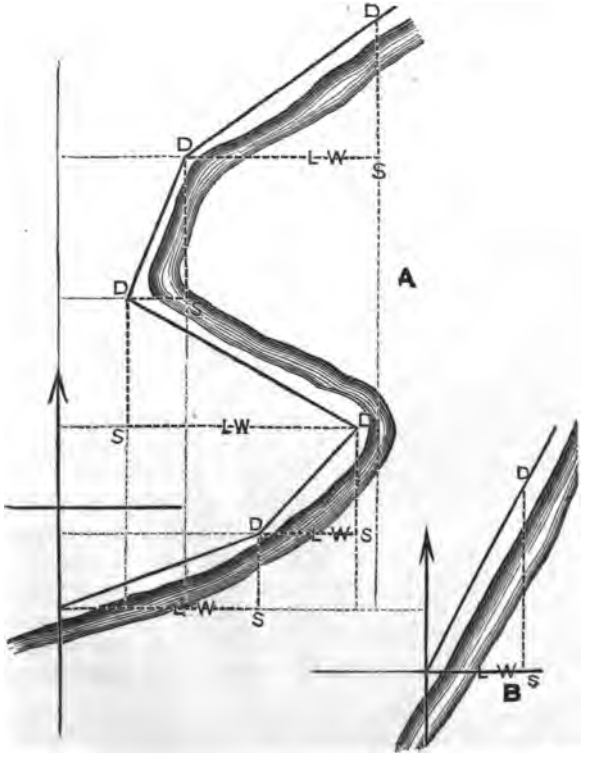
A main carrier is taken out of the river at a level sufficiently high to command the tops of the ridges; the water is carried by small trenches along the top of each ridge, and by means of temporary stops of turf is thrown over on each side, and received in the drain below, from whence it is collected into a main drain, and if possible carried on to water other ground. The ridges are usually from thirty to forty feet wide, and where there is abundance of water they are made sometimes sixty feet wide. The expense for this kind of irrigating work is of course much greater than that just above described; there is the forming of the ground, the excavating of large carriers, the sluices are larger or more numerous, and it often involves the necessity for weirs, permanent or temporary. We consider, however, that the improvement may be made at least correspondingly great.

CHAPTER VI.

TRAVERSE SURVEYING.

SINCE the introduction of improved theodolites, and a little better understanding amongst surveyors of the ordinary mathematical tables of natural Sines and Cosines, and of the Traverse tables which are, of course, based upon them, the best of which are simply the most correct and complete, Traverse Surveying has become much better understood and much more extensively practised.

We would, however, observe that there are two or three descriptions of traverse surveying commonly practised; in the



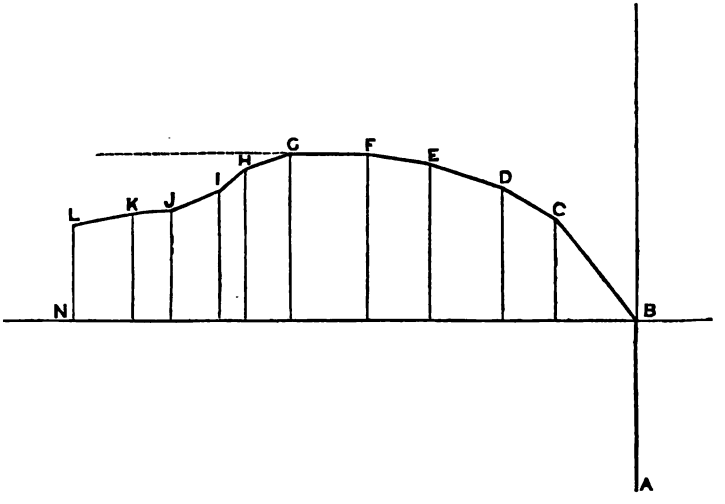
one case, if we go completely round any area with theodolite and chain, and plot the work with a protector, in the manner explained in the first volume of the "Practice of Engineering Field-Work," the work produced is called a traverse survey; in the other case, if a number of lines are chained, and the angles which they make with each other and with the magnetic are measured with the theodolite, but without completing a circuit, and these are plotted by means of traverse tables, as in the accompanying figure A, the work is also called a traverse survey; and this is even applied to the condition where even one line only is so surveyed and laid down, as in figure B. Unless where we find it advisable to adopt a system of triangulation, we have, for many years past, always practised the system of traverse surveying, as approximating the most nearly to a regular system of triangulation, and giving the same results when properly carried out. Both in figures A and B, the full lines represent the survey lines by the side of a river; the strong dotted vertical lines marked D S, represent the sines of the angles, or, as they are called, the "Northings and Southings," or Departures; whilst the strong dotted horizontal lines, L W, representing the Cosines, are called "Eastings and Westings," or Latitudes. The fine dotted lines explain how a system of plus and minus tables may be arranged to plot the whole, from two lines representing the meridian and the east and west.

As in the following we are about to refer to Mr. H. D. Haskold's traverse table,* we shall make use of his explanation in the description of traversing underground.

Suspend a fine copper wire or chain, with a plumb-bob attached, down the centre of the shaft A, in the accompanying figure, or in the absence of these, make a countersink hole in the cast-iron stricker-plate in the centre of the shaft; then place a lamp directly over this, and advancing along the line to the next turn in the road, drive into the ground an iron peg as at B, the first station; proceed along the line, and at every bend drive an iron peg to mark the successive stations; it will also be a good precaution to mark the sides of the rock with white paint; to show the stations more readily. The Surveyor may now return to the commencement, and after setting the instrument exactly over the centre of the station B, level it; and clamp the upper plate to Zero of the lower plate, and release the body clamp; turn the whole instrument round in the direction of it, and bisect it, with the cross hairs of the upper telescope of the theodolite, by the

* "A Practical Treatise on Mining, Land and Railway Surveying." Atchley and Co., 106, Great Russell-street, Bedford-square.

body tangent; release the upper plate and turn it round till the telescope bears on the second or forward station C, (or the flame of the lamp placed over the iron peg previously driven); clamp and mark the bisection as before with the upper tangent screw; read off the angle, say 140° 20′. If now the same operation is gone through of bringing the plates to Zero, and sighting to the forward station C, as a back station, and also on A as a forward



station, the second reading plus the first should be exactly 360°, say the second reading 219° 40′ + 140° 20′ = 360.° The instrument may now be removed to the second station C, and again set up and levelled, thus bringing the plates again to Zero, and on the lamp brought forward to the first section B; the upper plate is then released, and directed to the lamp placed over the third station D; the bisection is now made, and the angle read off as before. The instrument is then taken forward to the fourth station E, and the same operation gone through, the theodolite and the lamps changing place alternately from station to station, until the whole is completed.

The surveyor may then return and proceed to measure the distances between the stations; the lamps are again to be placed on the forward stations in turns, and the surveyor taking the hind part of the chain, directing the forechain man in line, and towards the forward station, entering down from time to time the measure of the different lengths, (as also any particulars or remarks he may find necessary), until the whole are measured.

He must be prepared with a survey book ruled into as many columns as will be required, and headed—1st, No. of drafts or hypothenuses; 2nd, angles of inclination; 3rd, measured distance in links; 4th, horizontal angles; 5th, remarks, &c. The surveyor being now provided with proper assistants, and a book of the form stated above, he will commence a survey of the heading A, B, C, D, E, &c., to L. From a chain suspended down the shaft at A, set up the theodolite at B, and after levelling, and clamping the plates at Zero, bisect the chain with the cross hairs of the telescope; release the upper plate, and direct the telescope to the forward station C, entering down Zero in the column headed horizontal angles, and the length of the line A B in its proper column opposite it; now read off the angle pointed out on the instrument, and enter it down in the column appointed for the horizontal angles. The assistant will then measure the line B C, which he will enter down in its own column, also any remark that may occur at the time; remove the instrument to the station C, level and clamp at Zero, and bisect the back station B; again release the upper plate, and point the cross hairs to the station D, read the angle off the limb, and enter it down in its column, while the chainmen are measuring the line C D; they will now call out the measurement, which must be entered down as before. It is to be remembered after reading off the horizontal angles the vertical ones are also to be read off, if any, from the vertical circle, and entered down as before. It is to be remembered that after reading off the horizontal angles, the vertical ones are also to be read off, if any, from the vertical circle, and entered down as elevation or depression accordingly. Proceeding as above, we arrive at the conclusion of the survey, which will stand in the survey book as follows.

If it is required to draw a plan of the traverse from the preceding survey book, it may be accomplished with the assistance of a circular protractor and chain scale, the former divided into minutes, the same as the theodolite. The horizontal angles are however to be reduced to angles from the first line, as a meridian to the whole, previous to being plotted.

Survey Book, No. 1.

No. of Hypothenuses.	Angles of Inclination.		Measured Distance in Links.	Horizontal Angles.	Remarks.
	Elevation.	Depression.			
1	0° 0′	0° 0′	400	00 Zero.	Opposite No. 1,
2	—	—	700	149° 20′	cross cut.
3	—	—	300	160 10	
4	—	—	400	170 40	
5	—	—	350	166 30	
6	—	—	420	172 20	Opposite to a
7	—	—	250	156 20	fault going up.
8	—	—	150	164 40	
9	—	—	300	192 20	Opposite No. 2,
10	—	—	220	196 40	cross cut.
11	—	—	300	184 20	

TO REDUCE HORIZONTAL ANGLES TO PLOTTING ANGLES FROM ONE STATION.

Rule 1st. If the first line in any survey is assumed as a meridian, and going Southward, and the first observed angle from it is less than 180°, it inclines to the east, but if more than 180° to the west of the first line; in the former the angle as observed is to be called No. 1, and in the latter, the difference between it and 180°, is to be called No. 1 plotting angle; but if the first line assumed as a meridian, is going northward, and the observed angle is less than 180°, it inclines to the west, and if more than 180°, it inclines to the east of the first line, the angle in the former and its differences from 180° in the latter to be called No. 1 plotting angle.

Rule 2nd. To No. 1 plotting angle add the next observed horizontal angle; if the sum exceeds 180°, take the amount from it, the remainder will be No. 2 plotting angle; to No. 2, add the next horizontal angle, and proceed as before for the plotting angles. Sometimes however the sum will exceed 360°, and in that case a whole circle, or 360° must be deducted from it for the plotting angle, taking the horizontal angles in Survey Book No. 1 as an example. The first angle is 140° 20′, and to the eastward of the first meridian; and the reduction to angles from one station is explained as follows.

140°	20′	= No. 1,	Plotting angle.	90°	0′	= No. 5,	Plotting angle.
160	10			156	20		
300	30			246	20		
180	0			180	0		
120	30	= No. 2,	„	66	20	= No. 6,	„
170	40			164	40		
291	10			231	0		
180	0			190	0		
111	10	= No. 3,	„	51	0	= No. 7,	„
166	30			192	20		
277	40			243	20		
180	0			180	0		
97	14	= No. 4,	„	63	20	= No. 8,	„
172	20			196	40		
270	0			260	0		
180	0			180	0		
90	0	= No. 5,	„	80	0	= No. 9,	„ &c. &c.

The reduced angles should now be collected from amongst the preceding work, into a tabular form ready to be plotted, as below.

Plotting Angles.

No. 1	= 140°	20′
2	= 120	30
3	= 111	10
4	= 97	40
5	= 90	0
6	= 66	20
7	= 51	0
8	= 63	20
9	= 80	0
10	= 84	20

To Construct the Plan.

Draw a line through any convenient part of the paper, and make a fine pencil mark on it; apply the centre of the protractor to this mark, and the notches marking the Zero and 180° on the instrument on the same line; to prove if the protractor has been

correctly set, bring the vernier to Zero, and unfold the arms of the protractor, carrying small fine points at each end; if these points strike exactly on the line, it is properly set; the angles No. 1, 2, 3, 4, 5, &c., may now be marked off, taking care to number them in the drawing in succession as they were taken from the table; remove the protractor and apply a chain scale; mark off 400 links on the back, or Zero line, A B; set a rolling parallel ruler to angle No. 1, and the centre it was marked off from; run it to station B, draw the line in this direction, and lay off with the same scale 700 links; bring up also angle No. 2 to the station C, and draw also another line in this direction; mark off on it the distance 300 links; apply the parallel ruler to each angle in succession, bringing them to the last station arrived at, remembering to make every line its proper length before bringing up another angle; proceed in this manner until you arrive at the last station L; lines may now be drawn parallel to the centre ones, which will represent the sides of the heading, and the plan will be completed.

The plan may also be constructed from data calculated from the elements given in the Survey Book, without the use of the protractor. The first step is that of reducing the observed horizontal angles contained in Survey Book No. 1; to angles from the first line A B as a Meridian, or their complements, from the East line B N.

Rule 1st. If the angles are less than 180°, deduct them from 180, and call the difference + ; and if more than 180°, deduct 180°, and call the difference —.

Rule 2nd. Add together the angles marked + and deduct those marked —: the remainder will be the angles to be employed, if the horizontal angle were taken from the East line or plane of latitude, or their complements, if taken from the assumed meridian.

Taking again the observed angles in the Survey Book No. 1 as an example, the reduction will be as follows:—

No.				
	1 = 180°	0′ — 140°	20′ = 39°	40′ +
	2 = 180	0 — 160	10 = 19	50 +
	3 = 180	0 — 170	40 = 9	20 +
	4 = 180	0 — 166	30 = 13	30 +
	5 = 180	0 — 172	20 = 7	40 +
	6 = 180	0 — 156	20 = 23	40 +
	7 = 180	0 — 164	40 = 15	20 +
	8 = 192	20 — 180	0 = 12	20 —
	9 = 196	40 — 180	0 = 16	40 —
	10 = 184	20 — 180	0 = 4	20 —

The angles marked + and — may now be collected and disposed in the following manner:—

						Complements to the First Series.	
No. 1 =	39°	40′ +	No. 6 =	23°	40′	50°	20′
	19	50 +		15	20 +		
2 =	59	30	7 =	39	0		
	9	20 +		12	20 —	30	30
3 =	68	50	8 =	26	40 —		
	13	30 +		16	40 —	21	10
4 =	82	20	9 =	10	0		
	7	40 +		4	20 —	7	40
5 =	90	0	10 =	5	40	0	0

The angles 1, 2, 3, 4, &c., are those to be employed in the calculation, and are separated into two series, the first as far as No. 5, which last is in an eastward direction; and it would be much easier in plotting to assume this as a new zero line. The data found by calculation from the first series may then be called a positive, and that from the second a negative quantity. The sines of the complements of angles of the former, multiplied by the measured distances, will give the perpendicular, and the cosine the base; in the latter, the sine of the angles, multiplied by the measured distance in links, will give the perpendicular, and the cosines of the angles, multiplied by the measured distance, the base.

THE END.

Will shortly be published, Second Edition of First Volume.
Re-written, with considerable additions, making the work a complete guide in the modern practice of "Engineering Field Work," including all the latest improvements at home and abroad. **Price 24s.**

THE PRACTICE

OF

ENGINEERING FIELD WORK

APPLIED TO

Land and Hydraulic,

HYDROGRAPHIC & SUBMARINE

SURVEYING & LEVELLING,

FOR

Railways, Canals, Irrigations, Roads,
Waterworks, Rivers, Docks and Harbours, Navigations,
Telegraphic Cables.

THE USE OF

SURVEYING AND LEVELLING INSTRUMENTS;
BAROMETERS AND THERMOMETERS FOR LEVELLING;
DEEP SEA SOUNDINGS AND CURRENTS;
THE TEMPERATURE OF CURRENTS.

AND

A Complete Treatise on Setting out Curves.

By W. DAVIS HASKOLL,

CIVIL ENGINEER,

Author of "Railway Construction," 4 Vols., £5 5s., and "Engineering Field Work," First Volume, 20s.

London:

ATCHLEY & Co., PUBLISHERS

OF ENGINEERING AND ARCHITECTURAL WORKS,

106, GREAT RUSSELL STREET, BEDFORD SQUARE.

NEW PUBLICATIONS

ON

CHITECTURE, ENGINEERING, AGRICULTURE, SURVEYING,

BUILDING, DECORATION, AND THE FINE ARTS.

PUBLISHED BY ATCHLEY & Co.,

106, GREAT RUSSELL STREET, BEDFORD SQUARE, LONDON, W.C.

nt Carriage free, if a Post Office Order is sent Payable to ATCHLEY & Co., *at the Bloomsbury Office.*

New Architectural Works.

1.

Executed Examples by Modern Architects.

With 26 Plates, some folded, and Letter-press, 4to, Super-royal, Cloth, Price £2 2s.

The Contents of the Work embrace CATHEDRALS, CHURCHES, SCHOOLS, MANSIONS, PUBLIC BUILDINGS, ALTERATIONS, RESTORATIONS, and other Works. By G. GILBERT SCOTT, Esq., and other Architects.

THIS work is a first attempt to gather into a volume a varied selection of the works recently erected in the United Kingdom, so as to bring them before the student, that he may be aware of their existence, design, and treatment.

At a period when so much is being done in the capital and in the country, it becomes almost necessary that a diversified record should be made of some of the works that have employed the mind and genius of the Architects of the present day, let their purpose be what it may, whether they are works of magnitude or those of simple and utilitarian character.

There are countless publications devoted to single subjects, in the shape of designs, but as the larger portion of them have never been carried into execution, they are not generally considered worthy of being consulted or followed. It is to substitute the executed for the non-executed, as a better medium to follow, that the present work owes its existence; and it is trusted that the varied nature of the subjects it contains will offer a wide field for observation. In a first attempt it is hardly possible to mature and perfect, but should this volume prove acceptable to the profession, every care will be taken hereafter, in future volumes, to remedy any incongruity or incompleteness that may be found.

To embody a portion of the labours of men of professional reputation, must be doing something in the right direction, and as such we hope it will find favour, and be considered of professional value.

2.

In one vol., folio, Twenty-one Plates, beautifully lithographed by Messrs. DAY and HAGHE, price £2. 2s. cloth.

Schools and School Houses, Parochial and

NATIONAL, in the GOTHIC, OLD ENGLISH, TUDOR, and ELIZABETHAN STYLES, illustrated by a Series of Plans, Elevations, and perspective Views, with Estimates, and Descriptive Letter-press. By H. E. KENDALL, Jun., M.I.B.A., F.S.A.

3.

In one volume, folio, Thirty-six Plates, price £2 2s.

Street-Villa, and Cottage Architecture. By S. H. BROOKS, Architect. Author of Villa and Cottage Architecture. Comprising a series of Original Designs for Street Elevations and Shop Fronts, in the Grecian, Gothic, Italian, Tudor, Elizabethan, and Louis XIV. Styles, Erections suited for new Railway Towns, and Buildings, for the embellishment of Gentlemens' Demesnes, giving Specifications, Estimates, Quantities, Prices, and numerous Practical Remarks; also several Improved Methods of Construction never before given in any Work, with Measured Drawings of Plans, Elevations, Details, Sections and Views.

4.

Cottage-Villas, Country Residences, Parsonages and SCHOOLS, with Elevations, Plans, and Estimates. By W. PATTISON, Architect. Folio, 33 Plates, cloth, 25s. "The Plans of this Work are very good."—*Building News.*

5.

In one oblong folio volume, cloth, price £1. 11s. 6d.

Modern Architecture. First Series. Comprising Examples of VILLAS and other DOMESTIC EDIFICES, erected in the Environs of London, with Twelve Plates of the various plans of each house. By different Architects.

1. Italian Villas, Kensington.
2. " "
3. Swiss " "
4. Italian " "
5. " "
6. " "
7. Parsonages in the Elizabethan style.
8. Villas.
9. Gate and Gamekeeper's Lodges.
10. Elizabethan Lodges.
11. Gardener's Cottages.
12. Villa, Camden Town.

6.

In one small folio volume, cloth, price, £1. 1s.

Modern Architecture. Second Series. Coloured Plates.

1. Gamekeeper's Cottage.
2. " Side Elevation.
3. Rectory House in Essex.
4. Parsonage " Brighton.
5. Terraces in the Suburbs of London.
6. " "
7. Terraces in the Suburbs of London.
8. " "
9. " "
10. " "
11. Farm House.
12. " side Elevation.

7.

In one small folio volume, cloth, price, £1 1s.

Modern Cottage and Villa Architecture. Third SERIES.

13. Villas near Regent's Park.
14. Regent's Villas.
15. " "
16. Villas, Notting-hill.
17. " Regent's Park.
19. Elizabethan Villa, Notting-hill.
19. Elizabethan Villa, Stockwell.
20. Hollyfield Villas, Surbiton-hill.
21. Italian " Notting-hill.
22. " " "
23. Elizabethan "
24. Italian " St. John's Wood.

8.

Habershon's Half-timbered Houses. Folio, Cloth, beautifully executed India Proofs, £3. Only 24 copies left.

9.

IN one splendid Imperial Folio Volume, very handsomely bound, with Emblematical Devices on the side, price £5 5s.

Illustrations of Windsor Castle. Dedicated to Her Most Gracious Majesty, QUEEN VICTORIA, and H R.H. the PRINCE CONSORT. Pictorial and Practical Illustrations of Windsor Castle, from a series of Original Drawings, made expressly for this Work, by Messrs. GANDY and BAUD, Principal Assistants to the late Sir Jeffry Wyatville, during the whole of the great Repairs and Alterations at the Castle, with Historical and Descriptive Letter press, by JOHN BRITTON, Esq., F.R.I.B.A., F S.A., &c.

This truly splendid Publication, after a large outlay, and very considerable personal trouble, is now finally completed, and the Publisher is anxious that the Nobility should judge for themselves that the work is really worthy their patronage, and of the noble building it professes to illustrate; he therefore feels confident that whether bound as a volume, treasured in a portfolio, or framed for general admiration, this book will long remain without a rival.

Only a few copies left.

10.

Octavo size, containing 1000 Pages of Letter Press, with Illustrations, in 2 Vols.
Price, Bound, £4.

The Handbook of Specifications; or, Practical Guide to the Architect, Engineer, Surveyor, and Builder, in Drawing-up Specifications and Contracts for Works and Constructions.

Illustrated by precedents of Buildings actually executed by the following and other eminent Architects and Engineers:—S. Angell, Sir C. Barry, J. B. Bunning, H. Baker, — Cundy, J. Dobson, of Newcastle, B. Ferrey, J. P. Gandy, the late Thomas Hamilton, of Edinburgh, Messrs. Hittoff, and other Architects of Paris; J. Lock, C.E., G. Mair, T. Page, C.E., G. Pownall, J. Shaw, J. Simpson, C.E., G. G. Scott, W. Tite, M.P., T. H. Wyatt, Digby Wyatt, &c., Preceded by a Preliminary Essay, and Skeletons of Specifications and Contracts, &c., &c., and Explained by Plates and numerous Woodcuts. By THOMAS L. DONALDSON, PH. D., Professor of Architecture and Construction, University College, London, M.I.B.A., Correspondent of the Institute of France, Member of various European Academies of the Fine Arts. Accompanied by a Review of the Law of Contracts, and of the responsibilities of Architects, Engineers, and Builders. By W. CUNNINGHAM GLEN, Barrister-at-Law, of the Middle Temple, and of the Poor Law Board; author of various legal works.

11.

In one volume, folio, £7 17s. 6d.

The Remains of the Ancient Monastic Archi- TECTURE of ENGLAND. By J. POTTER, Architect. This volume illustrates Buildwas, Tintern, and Wenlock Abbeys, with Plans, Elevations, Sections, Details, and Views, from Measured Drawings.

12.

80 Fine detailed plates and letter-press, price £4 4s.

Hadfield's Churches of Essex. 4to.

13.

J. Potter's Specimens of Ancient English Architecture. Containing 28 Plates and Letter-press of Parish and other Churches, with full details. Price £25s.

14.

The Prinicpal Gothic Edifices of Europe. This grand work represents, for the first time in One Series, the chief Gothic Buildings of Europe. In order to guarantee the strict accuracy of each subject, even in its minutest details, the Artists and Lithographers, Messrs. SIMONAU and SON, visited every Monument, and made their drawings upon the spot.

It consists of an elegant Frontispiece, giving a view of the Church of Louviers, in France; and 24 Plates, all India Proofs (38 inches by 29).

LIST OF THE PLATES

The Town Hall of Louvain.
The Town Hall of Audenarde.
Antwerp Cathedral.
The Church of Sainte Gudule, at Brussels.
The Town Hall, at Ghent.
The Town Hall at Brussels.
Westminster Abbey.
Lincoln Cathedral.
The Cathedral of Wells.
York Cathedral.
Salisbury Cathedral.
"Notre Dame," at Paris.
The Metropolitan Church of "Notre Dame," at Rheims.
Rouen Cathedral.
The Church of St. Croix, at Orleans.
The Cathedral of Amiens.
Cathedral de Chartre.
The Church of St. Riquier, Picardy.
The Cathedral of Beauvais.
The Church of Saint Wulfran, at Abbeville.
The Cathedral of Metz.
Strasburg Cathedral.
The Cathedral of Friburg, in Briesgau.
Cologne Cathedral.

A few Copies only left, £12 12s. each, was published at £15 15s.

15.

Mansions of Paris. With full Details, com- plete. £4 4s. Fine detailed folio Work. This work exhibits the best Buildings, and Street Architecture in Paris.

16.

Mansions of Belgium. Full Details, com- plete. £5 15s. 6d. The best detailed Work published for Mansions, &c. This work is very fine, giving the best Architecture of Belgium.

17.

Hotel de Ville, with full Details, complete, £3 10s. A fine Work, Published at £7.

18.

In one Vol., Imperial 4to., Twenty-four Plates highly illuminated in Gold and Colours. Price £2 12s 6d., cloth.

Decorative Painting of the Middle Ages, as applied to ENGLISH ARCHITECTURE. Illustrated by a series of Specimens of Ceilings, Screens, Tombs, Wall Paintings, Pulpits, Pavements, &c., from various Cathedrals, Abbeys, Churches, Deaneries, &c., by E. L. BLACKBURNE, Architect, F.S.A.

DEDICATED, BY PERMISSION, TO H. R. H. THE PRINCE CONSORT.

Just published, in Super-royal Folio, Price SIX GUINEAS, *half-bound Morocco: in Columbier Folio, Price* TEN GUINEAS, *half-bound Morocco.*

The Arts connected with Architecture,

Illustrated by Examples in Central Italy, of

Stained Glass, Fresco Ornament, Marble and Enamel Inlay, Wood Inlay, etc.

FROM THE THIRTEENTH TO THE FIFTEENTH CENTURY.

BY J. B. WARING.

From Drawings lately purchased by the Board of Trade for the Department of Science and Arts.

This Work contains forty-one Plates, executed in the highest style of Chromo-Lithography.

By Vincent Brooks.

The following are the subjects of the Plates:—

No. 1.—STAINED GLASS.—St. James, Florence Cathedral.
2. " " Prophets and Saints, Florence Cathedral.
3. " " From Santa Croce, Florence.
4. " " From Santa Croce and Santo Spirito, Florence.
5. " " St. Paul, S. M. Novella.
6. " " From Lucca Cathedral (St. Matthew and St. Mark).
7. " " Virgin and Child, S. M. Novella, Florence.
8. " " From the Cathedral and SS. Annunziata, Arrezzo. [Pisa.
9.—FRESCO ORNAMENT AND FIGURES.—From San Piero, near Pisa, School of Giunto da
10. " " " From Assisi, by Giotto.
11. " " " Capella de' Spagnuoli, Florence, by Simone Memmi.
12. " " " Sacristy, San Miniato, by Spinello Aretino.
13. " " " Detail of ditto.
14. " " " A Chapel in Santa Croce, Florence.
15. " " " Town Hall, Siena, by Martino di Bartolomeo.
16. " " " Baptistry, Siena, (Fifteenth century).
17.—WOOD INLAY.—From the Chapel in the Town Hall, Siena.
18. " " From Pisa Cathedral,
19. " " From Pisa Cathedral (Choir).
20. " " From Assisi (Choir).
21. " " From Orvieto Cathedral. (Drawn by James Lockyer, Esq.)
22.—MARBLE AND ENAMEL INLAY.—From the Town Hall, Pistoria } Twelfth
23. " " " From the Baptistry, Florence. } and Thir-
24. " " " The Baptistry Zodiacal Circe, Flor. } teenth
25. " " " Various designs from the Baptistry. } centuries.
26. " " " Santa Croce Tombs (Fourteenth century).
27. " " " Santa Croce, a Renaissance Tomb.
28. " " " Centre Ornaments, Santa Croce.
29. " " " Pavements, Santa Croce.
30. " " " Pavement, Siena, by Beccafumi.
31. " " " Figures, Siena, by Beccafumi. [at Pisa.
32. " " " Pavements in the Siena Library and the Baptistry
33. " " " Marble Inlay, from Pisa.
34. " " " Orgagna's Shrine. Florence.
35. " " " Shrine of San Giovanni, Florence. } Silver Gilt.
36. " " " Shrine of St. James, Pistoria. }
37. " " " Font in the Baptistry, Siena.
38, 39. " " " Heraldic Ornaments, Arms, etc.. Florence.
40, 41. " " " Siena Fountain.

Descriptive and Historical letterpress is given, in order to make the work complete in every respect, and to render it as useful to students as to professional men.

A Bond has been entered into for £500 not to reduce the price of this Work

REVIEW OF MR. WARING'S NEW WORK.

The Arts connected with Architecture.

REVIEW FROM THE ATHENÆUM.

Examples of Stained Glass, Fresco Ornament, Marble and Enamel Inlay, and Wood Inlay. By J. B. WARING. Drawn on Stone and Printed in Colours by VINCENT BROOKS. (ATCHLEY & CO.)

THIS magnificent Domdaniel folio, is such a book as fifty years ago only a Government or a *dilettante* like Beckford would have ventured to publish,—since Art-illustrated works had then but a small public, and were intensely costly in production. But in this golden and hopeful age of our young art, Mr. Waring calmly passes through the press his bossy volume as big as a portfolio, by help of chromo-lithographs and drawings lately purchased by the Department of Science and Art—to which, we believe, he belongs;—and the best of the enterprise is, that here students too poor to travel have drawings of great Italian frescoes and wall decorations,—not merely truthful, but of the full natural size, and in the full natural colours. Mr. Waring, already known to the Art-world by his Italian and Spanish studies, his Crystal Palace Handbooks in conjunction with Mr. Digby Wyatt, and his designs for civic architecture, commences his book—which is dedicated to Prince Albert—by lamenting that Architecture has so long been studied without reference to the sister-arts of Sculpture and Painting, which are its decorating handmaidens. The Greeks knew better than this,—for the Parthenon was radiant with colours and peopled with statues;—the Moors knew better,—for their mural decorations made you forget their walls.

In stained glass that seems made of melted jewels, Mr. Waring gives us some very precious specimens from Lucca and Florence: burning blues, the reds of fiery martyr-robes, gold of the sun's own dye, green like the Swiss lake water or a bossy soda-water bottle, which is of a marvellous colour, lace-work of banded flowers, amaranth and violet, forget-me-not and everlasting chestnut browns, dear to Italian eyes, and the tone of a Titian's satyr skin. Such are the hues he dazzles our cold blue northern eyes with in his long triumphal procession of armed saints and hard-foreheaded preachers. Arches of lapis-lasuli, crescents of perpetual flowers, bow over the upward-turned brows of ecstatic Pauls and Peters: praying kings and suppliant servants of God shine in the robes of the blessed, and appear to us as in a luminous vision, in such chromatic harmonies that they come to us as in clouds of music or in strains of angel quiring. The welded glass shows like the Urim and Thummim of the High Priest, and seems in more glorious instances radiant with the very Shekinah itself. Mr. Waring's description of the Italian-Gothic style of mural decoration begun by Giunta da Pisa, and followed up by Cimabue, Giotto, Memmi, Gaddi, and Aretino, is a favourable specimen of his curt, simple, clear, accurate manner of Art-description.

From the frescoes, Mr. Waring descends to the ingenious wood-inlaying mentioned by Theophilus in his twelfth-century treatise, but first found now in Venetian ivory and wood boxes of two centuries later. Doors, presses, and sacristy seats were adorned in this way by means of a limited palette of dark and light woods used in veneers. Fra Giovanni, of Verona, in the sixteenth century, carried this art miles further, using slips of polished willow for his high lights, and artificially dyeing his other woods with strong waters, coloured infusions, and dark, penetrating, soaking oils. The Dominican monk, Fra Damiano, of Bergamo, excelled even this man, burning in his shadows, and, with inlaid wood, using such fine carpentry that no one's eye could detect the joint. This crafty monk produced landscapes and figures which France and Flanders afterwards improved, but finally let die. But lately the art has been revived for mere trade furniture. The light yellow figures in these examples contrast well with the low red-toned ground, and remind us of the pretty plaiding of Tunbridge ware.

In marble inlay Italy is also very rich, with its white lace-work on coal-black grounds, its signs of the zodiac, wheels of fortune, and flaunting heraldic emblems, its red and black roundels and lozenging and general geometric puzzle-work, where order looks harmoniously thrown into pleasing confusion. Rome, Ravenna, Lucca, are all full of specimens, and on the façade of the Pisa Duomo it is used with a zebra effect on large surfaces of wall. The early pavements of Siena have the figures cut in outlines, filled in with mastic; the ground is white, and the grey marble inlaid stands for shadows. They look like designs for huge brasses. In the Florence Campanile the tower becomes a mere show-card of geometrical patterns, so redundant and beautifully overdone is it. In pavements it soon got worn out, but it is admirably fitted for monumental slabs within rails or on walls, and sometimes for rarer spots in external wall surface, as round an arch or over a door. In one beautiful instance, in the Baptistry pavement in Florence, there is a great zodiacal circle of this inlay originally marked with incised lines. A double row of arches and columns radiate from the centre, the basis of the outer columns resting on the centre of the arches of the innermost circle, the whole being filled in with foliated ornament, in which are inserted the twelve zodiacal signs, and said to have been once part of a sun-dial.

Mr. Waring's suggestive and instructive book of Art-examples closes with a burst of gorgeous metal-work and enamels from Pistoia and other Italian cathedrals.

We thank Mr. Waring for a useful selection from his sketch-book, brought out, as all productions should be to be of full use, in all the grace and strength of their original outlines, and in all their bloom and glory of colour, that knows no autumn, till the star shall wither out and the sun itself shall fade away like a flower.

REVIEW FROM THE BUILDER PAPER.

The Arts connected with Architecture. Mr. Waring's Book. (ATCHLEY & CO.)

So elaborate, costly, and suggestive a work as that which has been produced by Mr. J. B. Waring, with the aid of Mr. Vincent Brooks, deserves to be set as prominently before those who are interested in the subject of it, or are likely to be acted on by it, as our means will admit of. To produce a work by means of chromolithography, containing forty-one large folio plates, blazing with colour, accompanied with historical and descriptive letter-press, on paper *de luxe*, solidly bound, involves no small risk financially; and the effort, when worthily made, as this is, should be supported by those who concern themselves with the arts of the country. It is not every individual, however well-disposed, who can afford six guineas for a book; but the more wealthy buyers, public bodies, municipal libraries, and schools of design, should consider it their duty to assist in such cases by the purchase of copies. For years our architecture has been bald and lifeless;—restricted to ill-understood imitations, and permitted no aid from her children arts.

The forty-one plates in the work before us are appropriated to stained glass, eight; fresco ornament and figures, eight; wood inlay, five; and marble and enamel inlay, twenty.

We hope the time is not far distant when the internal decoration of our own buildings will be made to afford opportunity for the development of our school of painting. What is being done at the West-minster Palace, Lincoln's-inn Hall, the church in Margaret Street, and elsewhere, will expedite the event. The Corporation of London, and the wealthy City Companies, should give their aid.

19.

Richardson's Remains of the Reigns of James AND ELIZABETH. Coloured, £6 10s. (Only 20 copies left.) This is the finest Work on Elizabethan Architecture ever published.

20.

In one volume, Imperial 4to, Twenty Plates, price 21s.

Examples for Exterior and Interior Finishings. By E. W. TRENDALL, Architect, Author of "Monuments," &c. Consisting of Entrance, Single and Folding-doors, Windows and Shutters, Chimney Pieces, Verandahs, Balconies, and sections of Rooms coloured, with their details drawn one-half real size, and ornamental Cornices coloured for different rooms, &c.; the whole forming a Book of Working Drawings. A most useful work for the Decorator, Builder, &c.

21.

The Builder's Guide and Price Book, in Materials and Construction, by G. D. DEMPSEY, C.E. New edition, with Supplement, containing 230 Illustrations. Cloth, £1 1s. This Work is a Practical Manual for the Builder, Clerk of Works, Professional Students, and others engaged or interested in Designing or superintending Building Works generally; it treats of Foundation, Masonry, Brick-work, Wood-work, Iron-work, Roofs, Fire-proof Construction, Drainage, Sewers, &c., &c. The work is allowed to be the best and most useful on the subject by the Profession.

22.

The Supplement, containing Working Drawings, Specifications, Estimates, Bills of Quantities, etc., and 65 Illustrations. Separate to Subscribers having the "Builder's Guide." Price 7s. 6d.

22*.

Ancient Domestic Architecture, giving the best examples in Great Britain. By F. T. DOLLMAN, Architect. About 160 4to plates and letter-press, half morocco, in 2 vols., £5 5s.

23.

Timber Roofs. Large folio detailed Plates, and 4to text. Price £1 11s. 6d.

24.

Tress's Working Drawings of Modern Churches. 4to, 16s.

25.

The Late A. W. Pugin's Church, called His "MODEL CHURCH," at Wymeswold. 4to Plates, and Letter-press, 21s.

26.

Mexico Illustrated. In 26 beautiful Litho-

graphed Plates, Letter-press in English and Spanish. Half Morocco, folio, £4 4s, or in a Portfolio, coloured, £10 10s.

"This volume is amongst the best of those books of lithographic views which modern art has hitherto produced. It contains 26 drawings of the scenery of Mexico, both of the natural appearance of the country, and of the architectural edifices of the towns and cities. The view of Jalapa is very beautiful, the distance carried out to a great expanse of view, and the figures in front ground well placed. The figures introduced add very cleverly to the general character. Rio Frio is amongst the best views. The march of the American troops is well introduced. The views of the city of Mexico, and of the exterior and interior of the celebrated cathedral, though of a different character, are entitled to equal praise. The architectural drawing is without stiffness, and the minute details are elaborate and artistical. The same may be said of the Church of Santo Domingo and of the Convent of La Merced, which last is very fine. In the view of Chapultepec, the artist has introduced a group of Lancers, which is full of spirit, and more than usually good. The effects of light and shadow in these views are managed with a skill, which a few years ago would have surprised, and which even in the present state of lithography show a steady and rapid approach to excellence."—TIMES.

Only a few Copies for Sale; the Stones are destroyed.

27.

First Series, Railway Construction: from the

setting out of the line to the completion of the works, for the Use of the Engineer, Contractor, &c. 2 Vols. By W. D. HASKOLL, C.E, Price £2 12s. 6d.

This Work is in 2 Vols. Imperial 8vo, containing about 200 Woodcuts and engraved Diagrams, with copious text, and about 40 Plates of executed works, the whole carefully figured.

Second Series, Railway Construction. 2 Vols.

By W. D. Haskoll, C.E. Illustrated with 90 folding plates, with French and English Scales of subjects, particularly useful to Engineers, Contractors, Students, &c. Price £3 3s. These 2 Volumes, completing Mr. HASKOLL'S work on "Railway Construction," bound to correspond with the former 2 Volumes; the 4 Vols. can be subscribed for at Atchley & Co's. for £5 5s.

Some of the contents of these two Volumes :—Difference in the conditions of Railways in Europe and in high thermometric and partially inhabited regions. Camps and Labour Stations: their establishment, present and ulterior value. Earthworks. Cuttings and Embankments. Roads, Rivers, and Streams. Summer and Flood Waters. Passenger Stations, Stores, Warehouses, and Sheds. Goods, Wagons, Cattle Wagons, and Cattle Pens. Masonry. Timber and treatment of Iron. Glass. Ventilation. Earthquakes. Minor stations, temporary or permanent. Timber bridges and viaducts, permanent or temporary, their design and construction. Stone and brick bridges, their design and construction. Aqueducts and Culverts. Wrought Iron plate girders, their design and construction. Wrought Iron triangular girders, their design and construction. Wrought Iron lattice girders, their design and construction. Wrought and Cast Iron in Piers, Pillars, and Foundations. Wing walls and retaining walls in a scale of graduated heights, from the best French and English Examples. Docks and Dock gates, Timber Jetties. Timber and Wrought Iron Landing Piers. Teredo navalis and creosoting. Cranes for various purposes of Timber and Wrought Iron. Wrought Iron and Timber fencing, gates, &c. Permanent way.

Also,

Second Series. 2 vols. in French, £3 3s.

28.

In one vol., octavo, Cloth, with Plates, £1.

The Practice of Engineering Field Work, ap-

plied to Land, Hydrographic, and Hydraulic Surveying and Levelling, for Railways, Canals, Harbours, Towns, Water Supply, Ranging Curves and Centre Lines, Gauging Streams, &c. Including the description and use of Surveying and Levelling Instruments, and the practical application of Trigonometrical Tables. Illustrated by numerous Plans and Diagrams. By W. DAVIS HASKOLL, Civil Engineer, Author of "Railway Construction," &c.

To remedy deficiencies, and at the same time to supply such numerous practical examples and rules as are constantly required in the multifarious operations of English Engineering Surveyors, now engaged in every quarter of the globe, and to bring these within the compass of one volume, have been the object of the Author's labours in the work now submitted to the Profession.

"We hear of 'French without a Master,' and Mr. Haskoll's book might fairly be called 'Land Surveying without a Master,' its instructions are so full and so clear. It begins at the beginning, and takes nothing for granted: and those who master its teachings will find few difficulties in the field they will not be able to overcome. In addition to what is shown of its scope by the title, the book includes notes on the description and use of surveying and levelling instruments, and the practical application of trigonometrical tables, and is illustrated by numerous plans and diagrams. We may safely recommend it."—*Builder*.

29.

In one Vol. 8vo., Price 10s. 6d., with large Steel Engravings of Simm's Theodolite, the Gravatt Level, and other Instruments, etc., etc.

Surveying, Levelling, and Engineering Arith-

metic; or the Present Practice of Surveying and Levelling. Being a Plain Explanation of the Subject, and of the Instruments employed. Illustrated with Suitable Plans, Sections, and Diagrams.

Dempsey's Works on Bridges, &c.

30.

Price £2 12s. 6d.

Malleable Iron Bridges: containing, First Series.

THE BRITANNIA BRIDGE, over the Menai Straits.
THE BRIDGE AT ST. GEORGE'S LANDING STAGE, Liverpool.
THE BRIDGE OVER THE RIVER TRENT, at Gainsborough.

These three Bridges, with the details of each, and a perspective View of the Britannia Bridge, by DAY & SON, in one Imperial folio volume. Plates, on Copper, bound in cloth, and Text 4to., cloth.

31.

Second Series. Brick Bridges, Sewers, & Cul-

VERTS. Each Example fully Exhibited in Working Plans and Sections. Imperial folio Plates, with 4to. Letter-press. Price £1 11s. 6d. By G. D. DEMPSEY, C.E.

32.

Third Series. Timber Bridges and Viaducts.

With full details. Folio Plates, 4to. Letter-press. £1 11s. 6d. By G. D. DEMPSEY, C.E.

33.

Fourth Series. Iron Bridges. With full details.

Folio Plates, 4to. Letter-press. £1 11s. 6d. By G. D. DEMPSEY, C.E.

34.

Fifth Series. Moving Bridges, Iron, Suspension,

AND OBLIQUE BRIDGES AND VIADUCTS. With full details. Folio Plates, 4to. Letter press, £1 11s. 6d. By G. D. DEMPSEY, C.E.

35.

Sixth Series. Stations, Engine-houses, Manu-

FACTORIES, WAREHOUSES, WORKSHOPS, &c., &c. By G. D. DEMPSEY, C.E. Price £2 12s. 6d., Imperial folio Plates, and 4to Letter-press.

This Work contains Elevations, Plans, and Sections of Buildings for general, and especially for industrial purposes; including Engineers' Workshops for Turning, fitting and erecting Machinery—Steam-hammer Shops—Smithery, Engine and Boiler-houses—Pumps and Wells, applicable to apparatus for the treatment of Sewage. Sections and details of Foundations, and of Fire-proof Buildings. Details of Iron Columns and Girders—Flooring—Sashes—Frames—Stairs; Sections of Girders, Wrought-iron Beams, and Sections of Cast and Wrought-iron for Sashes, Frames, &c., &c., &c.

36.

Examples of Iron Structures.

This work comprises illustrations of the application of Iron to the construction of Railway and other Works. 4to, with detailed Plates, price 10s. 6d. By G. D. DEMPSEY, C.E. Containing: Plates of Bridges, &c., by J. Hawkshaw, P. W. Barlow, J. U. Rastrick, R. Stephenson, and G. W. Buck.

37.

30 folio Plates, and Letter-press, £1 10s.

The Machinery of the Nineteenth Century.

By G. D. DEMPSEY, C. E. The Illustrations of "THE MACHINERY OF THE NINETEENTH CENTURY" will have the valuable character of mechanical exactness, being drawn to proper scales, most suitable for displaying the essential details of each subject. This exactness has been secured by preparing each subject under the superintendence of the Manufacturers whose works are thus carefully depicted.

38.

Examples of Iron Roofs, of various Spans, from

20 to 154 feet, comprising Practical Sections and details of the best Examples. Imperial folio Plates, 4to Letter press, 1st and 2nd Series, £1 11s. 6d., each. By G. D. DEMPSEY, C.E. 3rd Series, by F. CAMPIN, 15s.

39.

Incitements to the Study of the Steam-Engine.

2nd edition, enlarged. By W. TEMPLETON, Engineer. Cloth, 5s. 6d. This is the last work written by Mr. Templeton, and his best work.

40

New Upholstery Work, folio, with practical illustrations, half-bound morocco, with letter-press and title, £2 12s. 6d.

41.

Skeleton Structures on a New Principle, es- pecially adapted to STEEL AND IRON BRIDGES. By OLAUS HENRICE, Engineer. Cloth, lettered, 8vo, 16s.

42.

Blast Engines illustrated with large folding copper plate Engravings, giving working drawings, to scale, and letter press description. By H. C. COULTHARD, C.E. and M.E., folio, half morocco, £3 3s.

43.

A New Work on Mining, Engineering, Land and RAILWAY SURVEYING. Illustrated with numerous plates and diagrams, royal 8vo, cloth, 30s. By H. D. HOSKOLD, Mining Engineer.

44.

A Practical Course of Military Surveying and DRAWING. Illustrated with 38 Plates and 160 Woodcuts, by Captain LENDY, F.G.S., F.L.S., Director of the Military College at Sunbury, and Author of several Military Works. Imperial 8vo, cloth, 25s.

45*.

Steam on Common Roads, fully illustrated. By C. F. YOUNG, C.E., ALEXANDER L. HOLLY, and J. K. FISHER, Engineers. Cloth, 12s. 6d.

46*.

A New Practical Work on Mechanical Engi- NEERING; with also a Chemical Analysis of Iron and its Ores. Fully illustrated by 28 plates of Workshop Machinery, Boilers, Pumping, Rotative, Marine, Locomotive, Traction, and Steam Fire Engines, and 91 Wood-cuts. By FRANCIS CAMPIN, Engineer. 8vo, cloth, 27s.

New Works on Agriculture, etc.

45.

Farm Buildings and Labourers' Cottages.

With Plans and Estimates. By G. A. DEAN, Agricultural Architect. 4to., cloth. Price £1 11s. 6d. The best Work on the subject, with full details.

46.

The Land Steward By G. A. Dean, Agricul-

tural Architect and Surveyor. Royal 8vo. cloth, with Plates and Woodcuts. £1 1s. Containing Hints on the choice of Landed Estates, and means of increasing their value—Digest of the Law of Landlord and Tenant, Dilapidations, and Fixtures: and with a Supplement together. £1 6s. A valuable work for the Landed Proprietor, and others.

47.

Enfranchisement of Copyhold Property, with

Suggestions for ascertaining the Value of Existing Interests. Price 6s., containing, Origin and Antiquity of Copyhold Laws; Origin of Manors and Peculiarities of Copyhold Tenures, &c., &c., &c. "This is a valuable work to Landed Proprietors, Solicitors, Agents," &c., &c.—*Times.*

48.

Imperial 8vo, Cloth, £3 3s.

British Agriculture, containing the Cultivation

of Land, Management of Crops, and the Economy of Animals, Tables for Purchasing Estates, Dilapidations, Valuation, Rents and Tillage, Farm Agreements, &c., &c. Illustrated with about 200 Plates of Cattle, Implements, Buildings, Grasses, &c. Giving all the Improvements in the Cultivation of the Soil to the present time. By JOHN DONALDSON, Government Land Drainage Surveyor, etc., etc., and Author of various Agricultural and Scientific Works. Dedicated by Permission to HIS GRACE THE DUKE OF ARGYLE

"Omnium autem rerum ex quibus aliquid acquiritur, nihil est agriculturâ melius, nihli uberius, nihil dulcius, nihil homine libero dignius."—CICERO.

CONTENTS.

A Geological Notice of the Formation of the Earth.
A Notice of Ancient Agriculture, and to the present time — first writers mentioned.
On Soils, and the Special Cultivation, Rotations of Cropping, and Grass Seeds, for all kinds of Land.
On Farm Implements.
On Animal Manures.
On Vegetable Manures.
On Mineral Manures.
On Paring and Burning.
On Irrigation and Warping.
On Draining.
On Animals. — The Horse, Cattle, Sheep, Swine, and Poultry.
On Grain Crops.
On Root Crops.
On Grasses.
On Weeds.
On Noxious Animals.
On Grass Lands.
On the Dairy.
On Hops, the Cultivation, etc.
On Orchards, Trees, and Shrubs.
On the Garden; Bees, etc.
On Plantations, Forests, and Copses.
On Embankments, etc.
On Waste Lands.
On Farm Buildings.
On Fences, Gates, and Roads.
On Farm Accounts.
On Estate Agent and Farm Bailiff.
On Stocking Farms.
On Farm Agreements.
On Valuations of Rents and Tillages, Dilapidations and Wastes, Tables for the Purchasing of Estates. Leases, —Life Rent and other Rents.

49.

Price, 3s. 6d., 8vo, with many Large Folding Plates:
Shewing Plans, Sections, and Elevations of the Sewerage of London, and the means for remedying the existing evils.

Facts and Fallacies of the Sewerage System

OF LONDON AND OTHER LARGE TOWNS. Being a complete exposition of its enormous defects; shewing the pestilence spread by its deposits in the sewers, and the impossibility of removing the matter by flushing; with Plans for its purification, completely preventing the generation of poisonous gasses, and not permitting a particle of filth to enter the River Thames.

New Works on Monumental Sculpture, Ornament, &c.

50

Church and Conventual Arrangement, with

plates, and a Glossary. By M. E. C. WALCOTT, M.A. 8vo, cloth, 15s. This work should be in the possession of every Clergyman and Architect,

51.

Gibbs' Gothic Monuments, beautifully Litho-

graphed, 4to., £1 1s. This is a fine Book in the Florid Gothic style.

52.

Trendall's Tombs, Cenotaphs, Tablets, etc.,

with full details, by which the workman can erect each with facility. 4to., 30 Plates, cloth, £1 1s.

53.

Monuments, &c. By C. Tottie, Architect, 26

engraved copper Plates, folio, 30s.

54.

Headstones, Monuments, Tombs, and Orna-

MENTAL STONE AND IRON WORK: containing 70 to 80 Designs, complete and bound. By D. A. CLARKSON, Architect. £2 2s., 1st Vol. The best book on the subject.

55.

Grecian and Gothic Headstones, Monuments,

SLABS, ETC. ALL TO SCALE. Second Volume. By D. A. CLARKSON. 80 to 90 Designs, bound with Devices, £2 2s.

The "*Clerical Journal*" says, "These are every thing that can be required as Monuments for the Dead:—Mr. Clarkson well understands the subject."

A. & Co., will get out the Working Drawings for Mr. Clarkson's Works if ordered.

56.

Christian Memorials. By D. A. Clarkson; the 3rd Vol. on Monuments, 48 plates, £2 2s. Containing Headstones, Crosses, Tombs, &c., all to scale, imperial 4to, to match his two former volumes.

57.

Fonts, Mural Tablets, Chimney-Pieces, and BALUSTRADES; beautiful Designs, and well carried out to Plan and Scale. Bound, £2 2s. By D. A. CLARKSON, Architect and Sculptor.

58.

Gravestones, Tombs, Monuments, Crockets, ALPHABET, ETC. By ROBINSON. Cloth, £1 1s. Vol. 1. 21 Plates.

59.

Chimney Pieces; Original Designs, Elevations, Sections, Profile, and Plans. Imperial 4to, Cloth, £1 15s. A most useful work to Builders, Masons, and others.

60.

Gibbs' Ecclesiastical and Domestic Ornaments FOR THE WORKERS IN WOOD, STONE, AND METAL. 48 Plates, £1. Very beautiful Designs, and executed in the best style, or bound, &c., £1 5s.

61.

The Hand-Book of Ornament. Containing 100 Examples. Price 2s. 6d. A very useful and cheap work.

62.

New Ornamental Letters and Early English ALPHABETS; for Engravers, Masons, Decorators, etc. Taken from the Record Office of England, etc. Price 6s., cloth. The best work on the subject, being truthful.

63.

Barratt's Gothic Ornaments, well executed and arranged. Royal 8vo., 31 Steel Plates, cloth, £1 1s.

64.

New Drawing Book, by Grieve, Telbin, Absolom and others. The Overland Mail to India. 1s.

65.

Page's Acanthus. A Practical Work for the

Student and Amateur for Drawing every description of Ornamental Foliage, etc., and containing choice Examples in every style of Architecture, with descriptive Letter-press, illustrated by 200 Woodcuts and 60 Etchings on Steel. 8vo., 12s., cloth. A most valuable work to all Students.

"The producer of this Work—for he is it appears the author, editor, designer, engraver, and printer of it—is one of the masters at the School of Design ; and his object in publishing is to afford easy instruction by certain rules to enable the young draftsman to base his designs on safe and secure foundations. It is a most creditable production ; one that will interest all classes, and be of rare value to those whom it more especially concerns. The Author exhibits proofs of great industry as well as of patient research ; and where his own inventive powers are applied he is eminently successful. The book abounds in explantory illustrations of all the subjects considered—the style is clear and comprehensive; the merest tyro in art may study it with advantage. We rejoice to welcome a publication of the kind;—our English ornamental designers are, nearly all of them, slavish copyists, and scarcely dream of thinking for themselves. This cheap work, with upwards of two hundred engravings, and one hundred and fifty pages of letter-press, will, we trust, attract general attention, and recompense the producer of it."—*Art Union Journal.*

" This Work is one of the best and cheapest that has been written on the subject, and from the pen and pencil of a practical man, who has had the advantage of being able to see his instructions carried into effect under his own inspection, as director of the class of ornamental drawing at the School of Design ; as a further recommendation of the Work, it is worthy of mentioning, that the illustrations proceed from the graver, as well as the pencil of Mr. PAGE."—*Civil Engineer and Architects' Journal.*

" We hail with pleasure this Work, it has been long wanting in the School of Art: the rules are explicit, and the matter interesting and instructive; we doubt not but its success will repay the labours of the Author, who is the Alpha and Omega of the Work."—*Polytechnic Journal.*

" This is a Work in which great spirit for the benefit of the Arts is shown ; the rules laid down are excellent ; the whole of the Work is completed by the Author, which, to praise too much, would appear a bost ; it is illustrated with innumerable wood-cuts and plates. We wish the Work every success, and, in our opinion, no school or student should be without it."—*Weekly Dispatch.*

66.

Page's Decorator. A Series of 48 Plates, con-

taining Designs for Furniture in the Elizabethan and Louis Quatorze style, including Ornamental Alphabets, &c. 8vo. oblong, cloth, 6s. By the same Author as the Acanthus.

67.

Interior Decoration, 73 folio Plates on Cop-

per. £4 14s. 6d. This is a most elegant Work, and beautifully executed.

68.

Adams' Architectural and Sculptural Ornaments,

etc. 1 Vol. Gothic. 96 4to. Plates £3 3s. A most chaste Work on Gothic Sculpture and Decoration for the Architect, Sculptor, and Decorator.

69.

Ancient Iron Work, from the 13th Century.

Bound with Letter-press, Imperial 4to., or in 13 Parts, 6s. each. The drawings executed by D. A. CLARKSON, Esq. One of the choicest and best executed Works published. £4 4s.

This work will we trust create a new feeling in the Art Workman. We feel confident no work published gives the Artist so many beautiful forms as this.

70.

English Mansions, Villas, Lodges, &c., Imp. 4to, tinted plates, with plans, specifications, and estimates. Cloth, lettered, 4to, £2 2s. By F. ROGERS, Architect.

71.

English Cottages, for the Artisan and Agri- cultural Labourer, with tinted plates, plans, bills of quantities, specifications, all details, and estimates. Cloth, lettered, £1 1s.

72.

Detail Drawings and Sketches of Ecclesiastical AND DOMESTIC BUILDINGS of the middle ages in England and France. By F. ROGERS, Architect, in 1 Vol. 60 Plates, folio, half morocco, £2 2s.

73.

A New Work for the Office of the Architect, Engineer, Building Surveyor, Builder, Clerk of Works, &c. By W. D. HASKOLL, C.E., G. RENNIE, C.E. & M.E., & F. ROGERS, Architect. Cl., lettered, 5s. 6d.

74.

The Engineer's Pocket Remembrancer for Engineers, Architects, Surveyors, Builders, &c. An Epitome of Data, Rules, and Formulæ, applicable to Civil, Mechanical, Marine, Hydraulic, Lighthouse, Telegraphic, and Railway Engineering, Surveying, &c. By F. CAMPIN, C.E. Cloth, 5s. 6d. Second Edition.

75.

The Office and Cabin Companion. 2nd Edition. By J. SIMON HOLLAND, Chief Draughtsman Steam Branch of the Controllers of the Navy Department. Price 5s. 6d. These Tables are ordered to be used by the Admiralty.

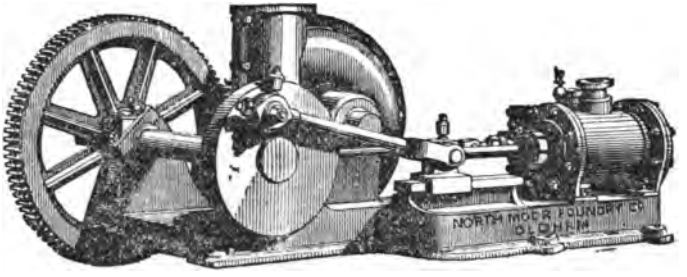
76.

The Law of Contracts, 8vo. By W. C. Glen. Barrister-at-Law. 8s. 6d.

TURBINE WATERWHEELS, PUMPS,

STEAM ENGINES, &c.

PRIZE MEDALS: Paris, 1867; London, 1862; Dublin, 1865; Paris, 1855.



Steam Engine and Centrifugal Pump, raising 140,000 gall. per hour to a height of 25 feet. Price £150.

IMPROVED PUMPING MACHINERY FOR SEWAGE, &c.

TURBINES.—CENTRIFUGAL PUMPS.—PUMPING ENGINES FOR WATERWORKS, IRRIGATION, SEWAGE, &c.

FANS FOR SMITHS' FIRES AND FURNACES.—EXHAUST FANS FOR DRIVING, VENTILATING, DUST, &c.—BLAST ENGINES.

VENTILATORS FOR COLLIERIES.—VENTILATORS FOR SHIPS.

KNIFE ROLLER COTTON GINS.—HYDRAULIC PRESSES.

STEAM ENGINES. — MILLWRIGHT AND FOUNDRY WORK.

References to nearly Ten Thousand Horse-power of Turbines, on any fall from 3 feet up to 1,050 feet.

THE NORTH MOOR FOUNDRY COMPANY,

OLDHAM.

PATENT APPOLD CENTRIFUGAL PUMP.

Messrs. EASTON,

AMOS AND SONS,

SOUTHWARK ST.,

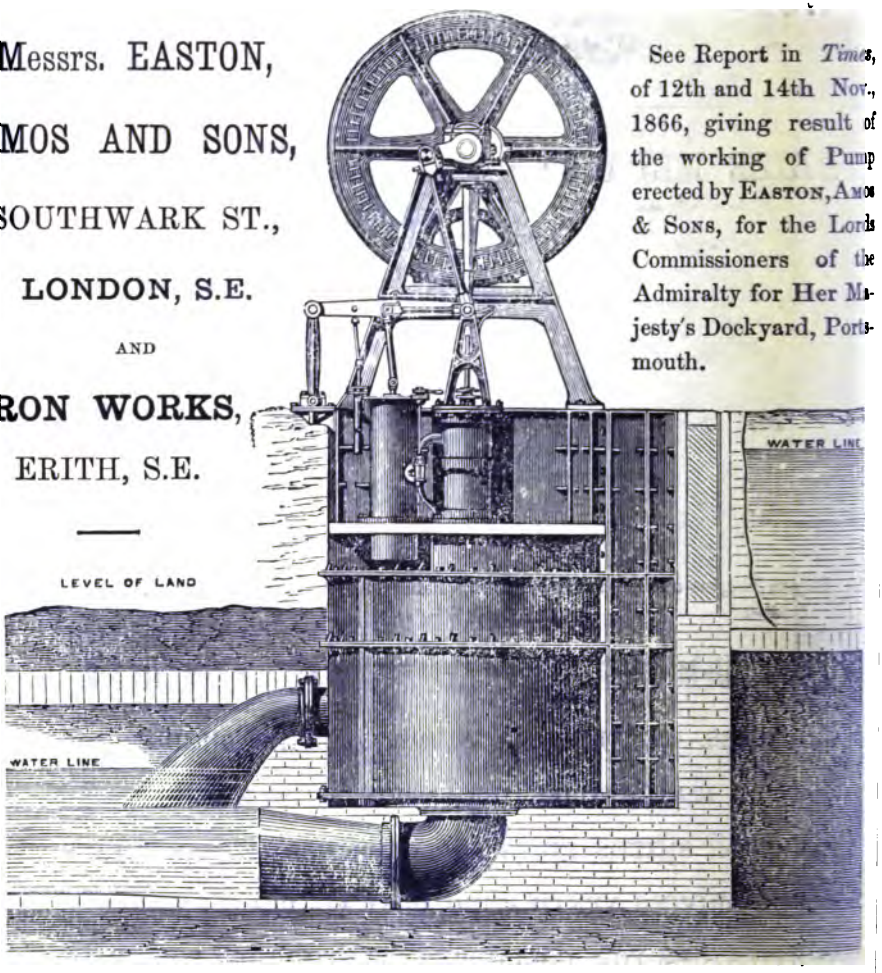
LONDON, S.E.

AND

IRON WORKS,

ERITH, S.E.

See Report in *Times*, of 12th and 14th Nov., 1866, giving result of the working of Pump erected by EASTON, AMOS & SONS, for the Lords Commissioners of the Admiralty for Her Majesty's Dockyard, Portsmouth.



The Patent Centrifugal Appold Pump obtained the Council Medal of the Great Exhibition of 1851, where, on trial, it was found to give a result equal to nearly 70 per cent. of the power expended. (*Vide* the Jury Reports.)

From experiments on Draining Machinery, made by order of the Court Policy of Demerara, in February, 1854, and detailed in the *Royal Gazette* of that month, the Centrifugal Pump of EASTON & AMOS did upwards of 50 per cent. more duty than any other machinery competing, which comprised scoop-wheel and centrifugal pumps by other makers. On this occasion, the quantity of water raised by the Appold Pump was 77½ tons per minute.

It obtained the Silver Medal of the French International Exhibition of 1855, giving similar good results.

In the International Exhibition of 1862 it still maintained its superiority, notwithstanding that considerable improvements had been made in other descriptions of centrifugal pumps.

By experiments made by Mr. D. K. CLARK, the Engineer of the Exhibition, by order of the Director of Works of the Admiralty, it was found that the large Appold Pump, by EASTON, AMOS & SONS, in the Western Annexe, performed 73¾ per cent. of useful effect of the power employed.

This result will be found to agree very nearly with that of the very elaborate experiments made upon the Appold Pump at the Great Exhibition of 1851. As compared with the other large centrifugal pump exhibited in the Western Annexe in 1862, Mr. Clark's report shows that the effective duty of the Appold Pump was as 73¾ per cent. to 58½ per cent.

During the last thirteen years EASTON, AMOS & SONS have manufactured and supplied a very large number of these pumps for every variety of purpose, and their experience shows that they can be strongly recommended in almost all cases, *except where a great height of lift is desired.*

ESTABLISHED 1795.

WORTLEY, JOSEPH CLIFF & SON, NEAR LEEDS,

MANUFACTURERS OF

SALT GLAZED SOCKETED STONEWARE PIPES

FROM 2 INCH TO 48 INCH DIAMETER.

PRICES OF LARGE PIPES FOR MAIN DRAINS AS FOLLOWS:

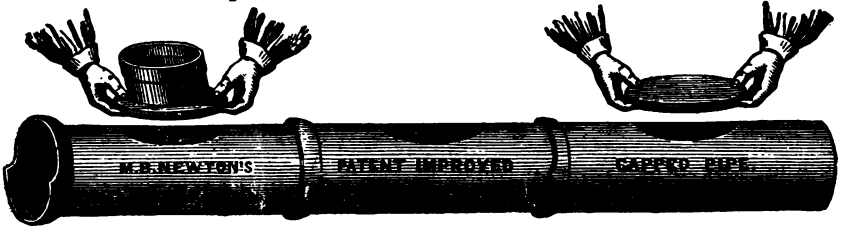
CIRCULAR.			EGG SHAPE.		
42 inch diameter	15/	per foot.	36 in. by 24 in. oval	7/6	per foot.
36 „ „	10/	„	30 in. by 21 in. „	5/	„
30 „ „	7/6	„	24 in. by 18 in. „	3/9	„
24 „ „	4/9	„	20 in. by 15 in. „	2/9	„
21 „ „	3/6	„	16 in. by 12 in. „	1/2	„

Smaller sizes Junctions, Bends, and Syphons, as per Lambeth List.

SOLE MANUFACTURERS OF

M. B. NEWTON'S Patent Improved Capped Pipe.

The most simple in construction of any Drain Pipe yet introduced.



Admits of the Drain being cleared without a single pipe being removed, and connection is made at any time by simply removing the MAN HOLE COVER, and inserting a Loose Junction Arm.

If these Pipes were laid one in every 20 feet, no *Drain* ever need he *disturbed* after once being laid down.

J. C. & SON, received the PRIZE MEDAL in 1862, International Exhibition, for

CLAY RETORTS FOR GAS & FIRE BRICKS,

And were the only English house who received Honours at Paris, 1866, for

FIRE GOODS OF ALL DESCRIPTIONS,

ALSO,

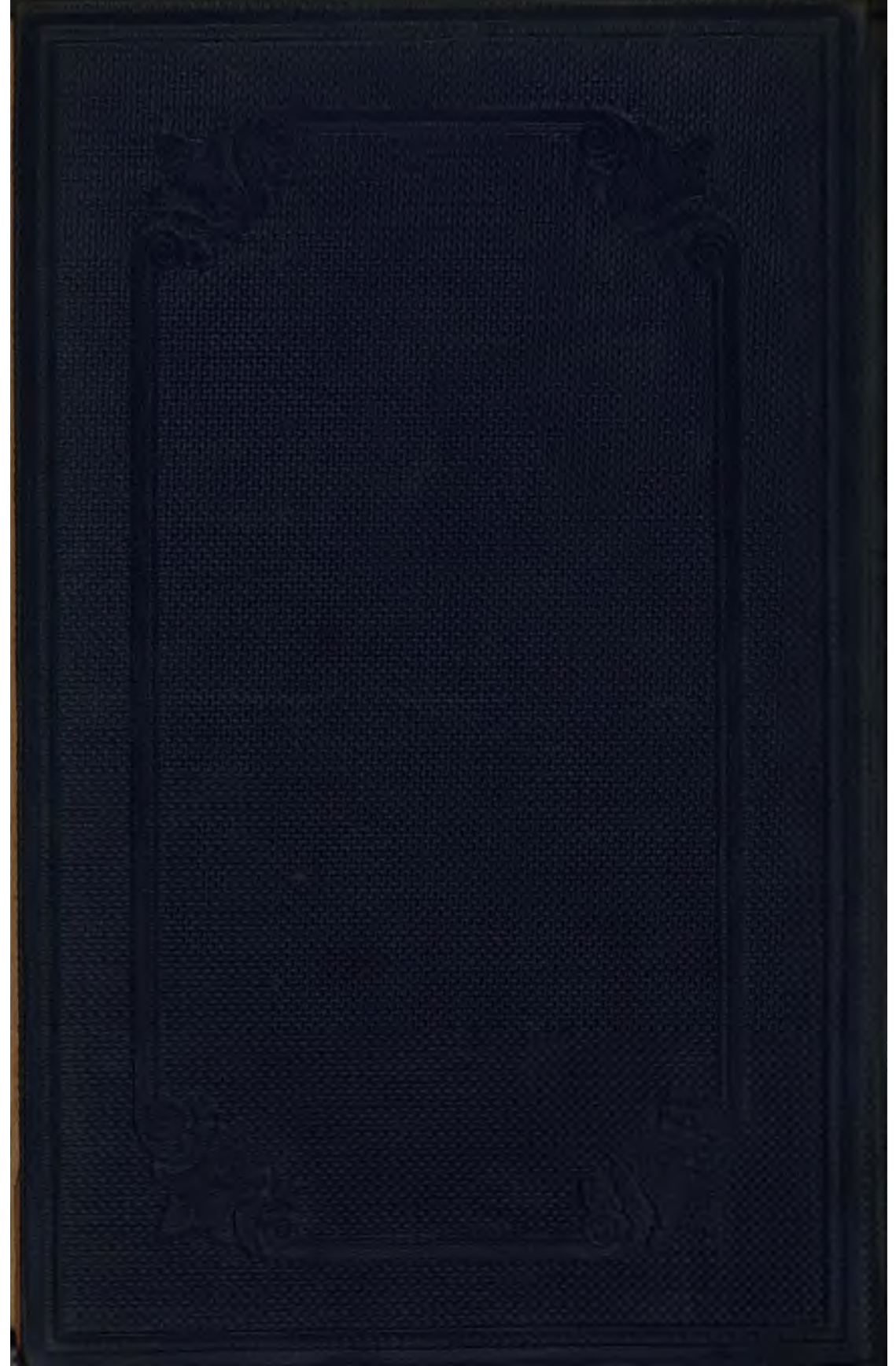
THE SILVER MEDAL FOR TERRA COTTA.

TERRA COTTA is now being used most extensively, and Architects will find their designs faithfully and artistically carried out; it is also the *most imperishable* of all ornamentation.

LONDON AGENT,

MARCUS BOURNE NEWTON,

Wharf No. 4, King's Cross Goods Station, N.

DEPOT FOR

Adamantine Clinke [illegible] *rdshire Ware, Tesselated* [illegible] *ricks.*